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BRITISH CHEMICAL ENGINEERING

A HEYWOOD TECHNICAL PUBLICATION

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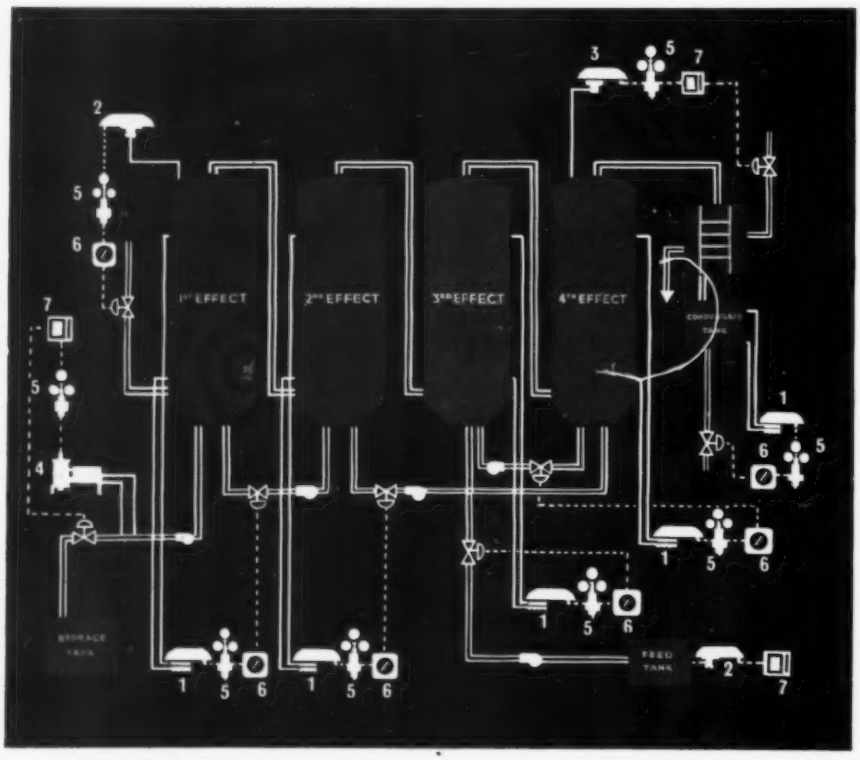

INSTRUMENTATION OF MULTI-EFFECT EVAPORATORS. Evaporators are an essential link in the chain of most chemical process and recovery operations. While all evaporators perform the same function—that of concentrating weak liquors—their design and operation may vary considerably from one industry to another, e.g. foodstuffs, paper pulp liquors, coal gas by-products, etc. Electroflo do not offer a stereotyped scheme for the instrumentation of evaporators. Depending upon the industry, type of evaporator and product, the extremely flexible pneumatic measuring and controlling systems are 'tailored' to the plant. The aims are ease of operation and efficiency of concentration.

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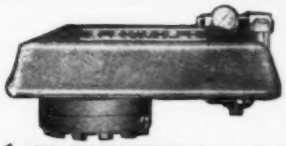

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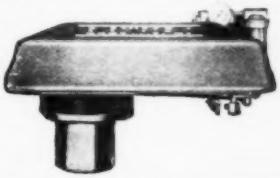

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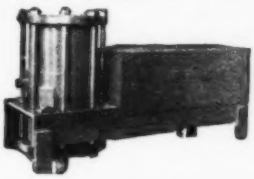

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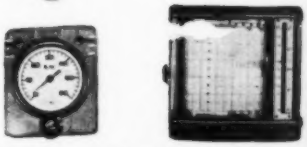

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BRITISH CHEMICAL ENGINEERING

DIGEST OF INDUSTRIAL AND TECHNICAL DEVELOPMENTS

New Plants and Processes

THE oil gasification plant now being installed by I.C.I. at Billingham for the production of hydrogen for ammonia synthesis will be unique in Britain. It will convert oil into a mixture of roughly equal parts of hydrogen and carbon monoxide. The starting material, heavy fuel oil, is injected into a furnace with steam and a limited amount of oxygen; and gasification takes place at a high temperature and pressure. The crude gases under pressure are led to a conversion plant, where they are reacted with steam to convert the carbon monoxide into the dioxide and produce more hydrogen. The next stage—removal of carbon dioxide—will be carried out by a Power Gas process using hot potassium carbonate solution.

A new process for conversion of oil under pressure into water gas will be used at the Shell plant at Shell Haven for the manufacture of ammonia. The Shell Haven intake of oil will be 200 tons a day. Evolved by n.v. de Bataafsche Petroleum Maatschappij, the process can make use of any hydrocarbon ranging from gas to heavy fuel oil as base material. Europe's first commercial unit is already operating successfully in Holland, at Ijmuiden.

Monsanto announce that a plant for the manufacture of cyclohexylamine (hexahydroaniline) is now in full production at their Newport factory. Part of the plant's output will be used by the company for the manufacture of rubber accelerators; part will be marketed as a chemical intermediate.

Wanted: 2,000 Technological Teachers

WE have pointed out that many more teachers are required if the Government's plans for the expansion of technological education are to succeed. We are glad to see that the new Minister of Education, Lord Hailsham, is fully aware that this is the limiting factor. Speaking to the Southern Advisory Council for Further Education, he said that the problem of creating a technical college system equal to current requirements must be regarded primarily as an equation in teachers. The White Paper envisages an increase in the annual output of advanced students of 15,000. The current output is about 9500. To teach the extra 5500, there must be about 2000 more teachers capable of taking advanced technological work. This is a tall order, in view of the fact that the total output of graduate technologists is only around 2300.

The situation demands a measure of rationalisation. Lord Hailsham explained that he did not visualise the cutting back of existing courses and the concentration of all advanced technological training in a few centres. That would not achieve the expansion we need, and in any case part-time advanced courses must be provided within reasonable travelling time of home and place of work. There must be a good spread of H.N.C. courses over the country, and for a considerable part of the expansion of advanced work the country will have to rely on these courses in the 150 or so area colleges. At present, however, many of these courses have very small numbers of students. "Our first objective, therefore, should be to strengthen these courses," remarked Lord Hailsham. When it comes to advanced full-time or sandwich courses, of university or near-university standard, he said that we would expect the students to go to the teachers rather than *vice versa*. For that reason the bulk of these courses should be concentrated in colleges of advanced technology and regional colleges. Lord Hailsham told the meeting that another name had just been added to the list of designated colleges of advanced technology—Portsmouth College of Technology.

Biochemical Engineering

LAST month's Leader on the future of biochemical engineering has created a good deal of interest. It brought in a large number of letters, and it also stimulated the B.B.C.'s European Service to do a broadcast on biochemical engineering.

In his comments on our Leader Prof. F. H. Garner of Birmingham University stressed the importance of the approach which progress in this branch of technology makes possible to solving problems of treating industrial effluents. We agree entirely with this point, for the necessity of clearing up our rivers demands that the fullest possible use be made of biological methods of treating these effluents. For instance, it looks as though cyanides can be treated biologically with advantage, while Monsanto have obtained promising results using organisms present in sewage to decompose the chlorinated phenols that have proved such a nuisance at Ruabon. Much more can be done in this field. Up till now there has been a tendency to rely on empirical methods, a "mixed bag" of microbes (such as sewage) being added to the industrial waste without anyone knowing which particular microbe or microbes may be the most effective agent for decomposing a particular pollutant. In the case of cyanide waste, one particularly effective organism has been isolated. The same kind of thing needs to be done for other pollutants.

No Lack of Research Problems

Biochemical engineering offers great scope for research, and we hope that there will be a rapid expansion of research facilities for fundamental studies in this field. Dr. A. M. Cook of London University's School of Pharmacy expresses the view that biochemical engineering (he actually favours the term *bio-engineering*) requires more cooperation between the bio-engineer and the biologist than exists between the chemist and chemical engineer. He suggests that this cooperation could very well start in the universities and technical colleges, and as the industries concerned command a large amount of capital it would be far-sighted policy for them to underwrite—even if only for a probationary period—a few chairs or fellowships in universities. We agree that this would be a considerable help towards the establishment of this subject. As we mentioned in the leader, a start has been made

at Birmingham University. There are rumours that both University College, London, and Imperial College of Science and Technology are thinking about following suit. We hope that these colleges will establish biochemical engineering units in the near future. What is quite certain is that once such a unit is set up, it will not lack for interesting research problems to investigate.

Intractable Mixtures

The Agricultural Research Council might well look into the possibility of financing some researches in this field. The A.R.C. has shown interest in the method of extracting protein from leaves which N. W. Pirie has been developing at Rothamsted. The latest estimate suggests that a large-scale plant would be able to produce proteins from that source at 1s. 6d. a pound, which is about the same as the cost of food yeast. This type of investigation is worth the support of organisations like the A.R.C. In this sphere there are plenty of problems to exercise the ingenuity of chemical engineers; an example is the handling of materials such as pulped leaves—materials with unusual or awkward consistencies—and this type of problem requires the development of new ideas. Mr. Pirie has contributed an interesting paper on biochemical engineering to *Research* (1957, Vol. 10, No. 1, pp. 29-34), and here among other things he mentions the possibility of improving extraction techniques to the stage where natural products (e.g. vitamins and intermediates for steroid hormone synthesis) might be isolated from plant tissues at an economic cost. He specifically suggests that the use of relatively specific adsorbents in the large-scale separation from complex mixtures of natural origin deserves to be intensively investigated, and he anticipates that a research and development programme would yield great improvements in the technique of handling mixtures that are at present intractable. He supports Dr. Cook's view about the kind of approach required in biochemical engineering, his comment being that "the biochemist is characterised by having chemical skill but biological interests—so also the biochemical engineer would have engineering skill and biological interests."

Petroleum Plant Supplies

DESPITE the Suez crisis the total sales of petroleum equipment, etc., placed in the United Kingdom in the last quarter of 1956 rose in value by over 29% to £39.5 million compared with the same period of the previous year, according to figures issued recently by the Council of British Manufacturers of Petroleum Equipment. Specialised equipment rose in value by 34%, to £1.2 million; instruments, meters, etc., by 18.2% to £500,842; pumps (excluding slush, oilwell, and kerbside) by 14.4% to £608,095, and chemicals by 5% to £6.1 million.

Testing Trade Effluents

METHODS of assessing the oxygen demand of trade effluents, which are new to British practice and which will be included in a recommendation now being prepared by the joint committee of the A.B.C.M. and the Society for Analytical Chemistry, were discussed by Mr. C. J. Regan at a recent meeting of the society at Bristol. They are the manometric (or respirometric) method of assessing the biochemical oxygen demand and the method of absorption from acidified boiling potassium-dichromate.

The manometric technique has great potential advantages for trade effluents, Mr. Regan pointed out, over the conventional bottle or dilution method. It avoids the need for large dilution when the oxygen demand of a trade effluent is great; moreover, the oxygen used up can be observed at any time, and a curve drawn showing the b.o.d. change over a period. Hence the nitration stage can be studied. Another advantage is that, by following the progress of the oxygen absorption in this way, the effects of any inhibiting substances that are present, and the lack of nutrients or seeding organisms, are apparent. The dichromate process was first devised in Britain—by Adeney in 1926—and has been much used in America. It gives results with many organic compounds much closer to theory than the older and simple permanganate value test; however, some of the carbonaceous and nitrogenous matter may not be oxidised. Practical experience by members of the committee has demonstrated its wide usefulness in connection with trade effluents.

Synthetic Detergents in Sewage Works

SYNTHETIC detergents have been causing a great deal of trouble in sewage works, and in his Royal Society of Arts lecture on the subject of detergents and public health Dr. B. A. Southgate (director of the D.S.I.R.'s Water Pollution Research Station) said that one solution of this problem would be to change somewhat the composition of the surface-active materials included in detergent mixtures to increase their vulnerability to bacterial attack. He added that there might be some difficulty in doing this, since comparatively small changes in chemical composition may greatly affect the detergent effect. A typical alkyl aryl sulphonate used in detergent mixtures consists of a benzene nucleus to which is attached a side chain of carbon and hydrogen atoms. Work both in Great Britain and America has suggested that compounds in which this chain is straight are more readily decomposed by bacteria than those with branched chains. Dr. Southgate said that the average concentration of alkyl aryl sulphonate in raw sewage now averages about 14 ppm, and a considerable fraction (around 50%) of that normally passes through all stages of treatment at the sewage works. Real deterioration of the filter beds begins when the concentration of surface-active matter reaches 15-20 ppm. Foaming has been most serious at activated-sludge plants. Various methods have been tried for reducing foaming in aeration tanks. The most successful up to now appears to be the addition to the liquor in aeration tanks of a liquid anti-foaming agent. At the Mogden sewage works, this method has been generally successful, at an equipment cost of about £5,000 and an annual cost of de-foaming agent of about £15,000.

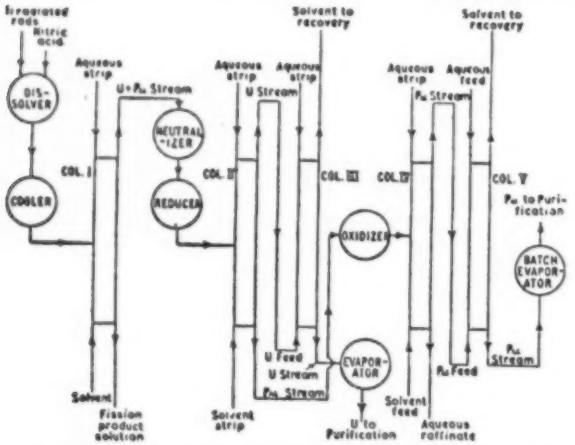
Instrument Industry Liaison

A COMMITTEE which served a useful purpose during the 1939-45 war in coordinating instrument production with national requirements has been revived in a form suitable to the needs of peace time as the Instrument Industry Advisory Committee. Set up by the Board of Trade at the industry's request, it will provide a forum for frank discussion between the industry and the Ministry on problems of mutual interest, and will act as a channel through which the Board can ascertain the views of the industry. On it will serve representatives of the Scientific Instruments Manufacturers' Association, The British Industrial Measuring and Control Apparatus Manufacturers' Association, the Instrument Section of the British Electrical Manufacturers' Association, the British Scientific Instrument Research Association, the D.S.I.R., the Ministry of Supply and the Board of Trade; other

Government departments will be invited to attend when their interests are concerned. The chairman is appointed by and the committee serviced by the Board of Trade.

Sellafield's "Old Horse"

THE WINDSCALE WORKS, which produces plutonium, has been operating for just five years. Originally the plutonium extraction was based entirely on that produced in the Windscale piles. Now Windscale will be handling uranium from the Calder Hall reactors, and it has enough



capacity to deal with the output of eight Calder Hall type (or PIPPA) reactors as well as the product of the two Windscale piles. This means it will be capable of handling everything from both Calder and Annan. With the big expansion of the CEA's nuclear power programme, a second Windscale unit will soon have to be erected; we anticipate that it will be added to the Windscale Works. Locally, the Windscale separation plant is affectionately known as "The Old Horse" probably because of its willingness "to be flogged." These points arose during the discussion following the paper delivered by C. M. Nicholls and Dr. R. Spence to the Institution of Chemical Engineers.

The process chosen for the Windscale Works by Dr. Spence's team was a solvent extraction process, using butex (dibutyl carbitol). The diagram shows its key stages. Irradiated uranium is dissolved continuously in nitric acid and passes to the first column, where the hexavalent uranium and quadrivalent plutonium are extracted into butex, which is stripped of fission products; the aqueous raffinate is concentrated before going to permanent fission-product storage. Then the solvent stream from column I is neutralised, and the plutonium reduced to the solvent-insoluble trivalent state by a selective aqueous reagent which does not affect the uranium valency. The resulting combination of solvent and aqueous liquor is fed to column II and extracted by a solution containing nitrate ion and stripped by butex. The uranium remains in the solvent and goes to column III; after back-washing, the resulting liquor is concentrated by evaporation prior to transfer to the uranium purification plant. (A full description of the process was given by Sir Christopher Hinton in his Castner Memorial Lecture, *Chemistry & Industry*, 1956, No. 27, p. 700).

Alternative Processes

The I.Chem.E. paper mentions other processes that might be developed for treating irradiated nuclear fuels. One of them depends on dissolving the fuel in bromine trifluoride, to convert the uranium into volatile hexafluoride. With bromine trifluoride, the cell in which the solution stage would be carried out would have to operate under pressure in order to maintain the liquid phrase; in the case of chlorine trifluoride, an excess of fluorine would be essential to repress the formation of chloride monofluoride.

Under investigation at Harwell are possible high-temperature metallurgical processes, which are designed to eliminate the expensive (metal—> solution—> metal) stage involved in the Windscale process. The idea is to keep the fuel in the metallic state and handle it by melting, slagging and vaporisation techniques. The recovered uranium would be radioactive, and therefore its fabrication into the next "generation" of fuel elements would have to be done under remote control.

The author's final conclusion is that processing plants will need to be versatile for some time to come, because neither reactors nor fuel element design have yet become standardised. Over the next few years, solvent extraction processes will remain in favour, and probably the second Windscale separation plant will operate a process very similar to that already used.

Trebled Output of Nuclear Power

A VAST expansion of Britain's nuclear power programme has been announced by Lord Mills, Minister of Power. The target is 5000-6000 megawatts of nuclear power by 1965—about treble the estimate made two years ago, and equivalent to 15% of the total generating capacity in 1965. This would mean the saving of some 18 million tons of coal a year. Lord Mills spoke of sixteen more power stations being needed, besides Berkeley, Bradwell and Hunterston. The cost would be about £1450 million; conventional power stations to do the same job would cost £810 million. He did not underestimate the very heavy burden this would make on the nation's capital resources. Average construction costs per kilowatt of installed capacity are estimated at about £125 for nuclear power; for the first two CEA stations in England, the figure is £145 per kilowatt, though a much lower estimate —£100—applies to the Scottish stations being built by G.E.C. and Simon-Carves. The plans have come in for some powerful criticism. The critics say that this programme would tie up much too big a proportion of our scientists and engineers. According to the Paymaster-General, all the stations envisaged in the scheme would be of the Calder Hall type and some people think that this type of generator may be obsolescent by 1965.

Atomic Energy in Australia

AUSTRALIA'S atomic energy project is now developing very rapidly. The research establishment at Lucas Heights is making impressive progress, and by the end of this year the DIDO heavy-water reactor (an exact duplicate of Harwell's), which Head Wrightson Processes Ltd. are building at a cost of just under £A1 million, should be divergent. The chief scientist of Australia's A.E. Commission, Mr. C. N. Watson-Munro, has just returned after a long spell he has spent gaining "know-how" at Harwell.

Production of uranium oxide is being greatly expanded. The Mary Kathleen deposit near Mt. Isa—the finding of this brought £25,000 to its discoverer—will be exploited under a Commonwealth Government contract covering production of oxide worth £40 million. The firm responsible is Mary Kathleen Uranium Ltd, in which Rio Tinto holds a major interest. The Government of South Australia is showing very keen interest in the possibility

of starting nuclear power production, and this State is most likely to be Australia's pioneer in that direction as it has poor coal reserves and lacks the water for hydro-electricity.

A radio-isotope exhibition has just been held in Sydney; organised by the Australian A.E.C. and Harwell's Isotope Division, it demonstrated uses in industry and agriculture. Among the exhibits were samples of bread, cheese and meat preserved by isotopic irradiation.

The new chairman of Australia's A.E.C. is Prof. J. P. Baxter, A.M.I.Chem.E., director of the New South Wales University of Technology.

The M.O.S. Chemical Inspectorate

THE history of the Chemical Inspectorate of the Ministry of Supply is related very readably in the official booklet entitled *Chemical Service in Defence of the Realm*, written by the well-known technical journalist, W. G. Norris. This organisation originated in 1854 as a small testing unit of the War Office, but its first head, Frederick Abel, established a strong tradition of research and development. During the succeeding years, as the booklet explains, this led to the growth of a chemical organisation whose work not only is vital to the supply of weapons, explosives and other materials for the Armed Forces but also plays an important role in the elaboration of new materials and processes with civil applications. Much of the text is devoted to describing the testing research and development work on products so diverse as plastics, rubbers, lubricants, paints, textiles, explosives, pyrotechnics, building materials, penicillin and packaging materials. The exigencies of the World War II and the rapid development of new materials imposed on the Inspectorate responsibilities whose size and technical difficulty could scarcely have been foreseen. The establishment's staff of scientists and assistants rose to a peak of 1600, employed in laboratories scattered throughout the country.

Monopolies Commission and Propane

THE latest document dealing with matters coming within the scope of the Monopolies and Restrictive Practices Acts is the 1956 annual report on this topic published by the Board of Trade. Three and a half pages are devoted to the supply of industrial and medical gases, most of this space being taken up by a summary of Monopolies Commission report (see *British Chemical Engineering*, Feb., 1957, p. 57). The final section of this part of the annual report refers to the supply of propane. British propane producers are as follows: (*a*) Shell Petroleum Co. Ltd., and B.P. Trading Ltd., with Eagle Oil and Shipping Co. Ltd., who sell through the common marketing agency of Shell-Mex and B.P. Ltd., has a restrictive understanding with B.O.C. (about 60%); (*b*) Esso Petroleum Co. Ltd. (about 35%); (*c*) Imperial Chemical Industries Ltd. (about 37%). The report adds that about 58% of the propane supplied by producers was supplied to B.O.C. and its subsidiaries; the conditions of the Act also prevail because B.O.C. and its subsidiaries account for about 59% and Saturn Industrial Gases Ltd. for about 36% of the propane supplied by distributors. The commission comes to the conclusion that there is competition between propane producers, with the possibility of increased competition from other refineries in the future. The commission's final comment is: "They have no evidence that prices have been fixed at a level which would yield excessive profits. In the field of distribution of propane they find that there is effective competition between B.O.C. and its chief competitor, Saturn Industrial Gases Ltd. They conclude, therefore, that the monopolistic conditions in respect of the supply of propane by producers and distributors do not operate against the public interest and may not be expected to do so in the future, provided that the present degree of competition continues."

In October, 1955, the Board of Trade asked the commission to investigate and report on the supply of certain chemical fertilisers. This was done under the 1948 Act. The commission is now looking into the matter to see whether the conditions of the 1948 Act as amended by Section 29 of the 1956 Act prevail, and if so to what extent.

Gibberellic Acid in Production

PAPERS referring to gibberellic acid have been published sporadically over the past three years, and now comes the news that Merck in the U.S.A. is to produce the potassium salt on a commercial scale. This news appeared in *Chemical Week* (Feb. 9, 1957), along with the information that another firm is going to market a spray containing the acid for use by amateur gardeners. Up till now giberellic acid has been produced only in research quantities.

I.C.I. has done a good deal of work on this very odd metabolic product derived from the fungus *Gibberella fujikuroi*, which was discovered by a Japanese plant pathologist called E. Kurosawa as long ago as 1926. The key biological work that has been carried out in Britain has been done by an I.C.I. group led by P. W. Brian of the Akers Research Laboratories; the corresponding chemical group has been directed by J. F. Grove.

Gibberellic acid has a remarkable effect on plant growth when supplied at extremely low concentrations, though the latest communication by P. W. Brian (*Nature*, 1957, Vol. 159, No. 4556, p. 417) says that it is not yet clear whether or not it acts like such plant hormones as indolylacetic acid. Probably, the most remarkable experiment yet performed with this substance involved a dwarf sweet pea; seeds of this genetic dwarf, which normally grows about 8 inches high, were treated with gibberellic acid and they proceeded to produce plants 3-4 feet high. Science knows of no other chemical which overcomes genetic dwarfness, and experts in this field are very interested in this discovery of what appears to be a chemical compound that is capable of making good a deficiency in a gene. Two other peculiar effects due to the acid have been observed. One is the breaking of dormancy in potato tubers. The second, discovered by Dr. Lang working in California, is that gibberellic acid induces spring-sown biennials to flower in their first season. The substance appears to possess great possibilities for horticultural and agricultural applications, though a good deal more research is obviously necessary before it can be released to farmers.

Forthcoming Conferences

THE second international congress of surface activity takes place in London during the period April 8-12. The membership fee for the congress is £4; enquiries should go to the Hon. Secretary, 2nd International Congress of Surface Activity, 14 Belgrave Square, London, S.W.1. A conference on what film and television can do in interpreting science to the public will be held at the French Institute, South Kensington, London, S.W.7, from April 4-6. Prof. P. M. S. Blackett will open the conference, and Sir Arthur Elton will speak on "Selecting the Subject." Mr. Edgar Anstey and Mr. Basil Wright are to discuss film production and Mr. Andrew Miller Jones and Mr. James McCloy will speak on television problems. The organisation responsible for this conference is the Scientific Film Association, 164 Shaftesbury Avenue, London, W.C.2.

BRITISH CHEMICAL ENGINEERING
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The Cost of Clean Air

THE technical aspects of the Clean Air Act are now receiving active consideration by all the interested parties, and the Institution of Mechanical Engineers has given a lead to the other professional bodies by organising a conference dealing with the engineer's contribution to clean air. Readers will find that the papers delivered to that conference are all worth examination. Here we intend to concentrate solely on the opening address of Sir Ewart Smith, who discussed some of the technical and economic factors involved in the reduction of atmospheric pollution. As an ex-chief engineer of Billingham, his views on this subject are worth a good deal.

Sir Ewart began by stressing the excellence and realism of the Beaver Committee's report. We endorse the well-merited tribute he paid to Sir Hugh Beaver, who has followed up his great work as chairman of the Committee on Air Pollution by taking an extremely active part in the public discussion of the committee's recommendation.

The Clean Air Act enunciated general principles on which government regulations covering technical points of detail are to be framed. Sir Ewart expressed the hope that these technical regulations will be introduced in stages, and that they will be so phrased that industry in general and the engineers responsible may know what is required and so be able to take effective action. The regulations will also need to be revised periodically in the light of administrative experience and as new technical knowledge materialises. He described the concentration of the Clean Air Act on the need to reduce smoke and dust—as opposed to the problem of controlling the emission of undesirable gases such as sulphur dioxide—as a wise and practical approach.

The Act raises many difficult problems for those who have to meet its provisions. First, said Sir Ewart they must interpret what is required in a technical sense—no easy task where no clear or simple standards exist. Secondly, they must decide how to meet these requirements in a practical and realistic manner at minimum cost.

The next passage in his address deserves to be quoted verbatim: *"The population at large must realise that not everything can be done in a day, but is equally necessary for industrial managers to remember that the standards of cleanliness required by the public through their servants, the administrators of the law, are rising continuously, as are the standards of performance which can be achieved."* The corollary of that point is this: any equipment to be erected in the future must be designed to take account of the most up-to-date knowledge and experience; otherwise it is soon likely to be the subject of justifiable complaint by the public.

What will be the cost of the remedial measures that are needed to minimise atmospheric pollution to reasonable limits? For the industrial side, Sir Ewart estimated that the total cost would be of the order of £350 million; on the domestic side the figure might be around £175 million. (That was the estimate which G. H. Goulden gave in his paper to the 1956 National Smoke Abatement Society Conference.) To get these figures into perspective, it is essential to think about the costs of existing atmospheric pollution to the community. The direct costs of pollution, according to the Beaver Committee, amount to about £250 million a year. This makes no allowance for readily available loss due to incomplete combustion of fuel, which may be put at no less than £25 million a year.

Regarded in this light, the capital costs involved in the implementation of the Clean Air Act cannot be regarded as intolerable. That is Sir Ewart's opinion, and it is one with which most technical experts are bound to agree. Sir Ewart suggested that this expenditure should be spread over at least fifteen years, and that the annual expenditure on clean air measures should be of the order of £40 million—equivalent to approximately 3% of the net annual expenditure on domestic fixed capital formation in 1955.

It is interesting to take a look at the various items which account for the £350 million estimate of industrial expenditure. First on Sir Ewart's list is £40 million, the cost of improving the efficiency of about 40,000 hand-fired boilers at an average cost of £1000 apiece. Secondly, there are some 2000 process furnaces which would need conversion at a cost of around £2500 each, or £5 million altogether. These two items of capital expenditure should give a good return through the resulting saving of fuel. The provision of dust arrestors would cost in all about £100 million. Sir Ewart considers that medium-efficiency cyclones will become necessary in respect of a consumption of 20 million tons of coal per year; these would cost £40 million. The remaining £60 million spent on dust-arresting covers the cost of the much more expensive electrostatic precipitators which may ultimately have to be installed in larger installations, including boilers, metallurgical and cement plants, etc.

Now that the Clean Air Act passes into the hands of the engineers, the rapid diminution of atmospheric pollution is seen to be a matter of practical politics. Within a generation, Britain's pall of smoke should have disappeared.

THE DEVELOPMENT OF A GAS/LIQUID SEPARATOR

by D. I. J. RODERICK and C. E. HIERONS*

In many industrial applications it is necessary to remove liquid from flowing gases. The liquid may be present as droplets or as a film adhering to the surfaces of enclosing pipework, or, more usually, as a mixture of both. The present work was undertaken at the B.C.U.R.A. to develop a separator suitable for the removal of water from wet steam where the quantities of moisture to be handled represented up to 25% by weight of the total mixture flowing in steam mains. In this article, however, an attempt will be made to present a broader picture of the factors governing separator design by incorporating the relevant findings of other workers.

WHEN a liquid is evaporated, a certain amount of the parent liquid is always entrained in the vapour produced. The way in which bubbles burst at the surface of a liquid has been studied by Newitt *et al.*[1] with the aid of high-speed photography. The stages in bubble rupture were demonstrated, and it was shown that the actual bursting of the bubble dome projected droplets a few microns in diameter into the vapour space. When the surrounding liquid rushed into the crater left by the bubble, however, a jet was formed which threw up droplets of the order of 0.1 cm diameter, and it is these larger droplets which are responsible for most of the entrainment. The proportion of droplets carried away with the vapour will depend on the relative velocities of vapour and liquid droplets. A droplet will be fully entrained only when its settling velocity is less than the velocity of the surrounding vapour.

Garner *et al.*[2] measured the size distribution of droplets emanating from water and potassium nitrate solutions in a pilot-plant evaporator. The method used was due to May,[3] and consisted of a two-stage cascade impactor with microscope slides coated with magnesium oxide for collection and measurement. Although 95% of the droplets entrained in the vapour space were below 20 microns in diameter, it was found that they formed a very small fraction of the total weight entrained because of their small mass. The major contribution to entrainment was found to come from droplets larger than 100 microns. Another finding of great interest from the point of view of separator design was the amount of entrained liquid which separated out in the offtake from the evaporator. Over a range of vapour velocity in the vapour space of 0 to 5 ft/sec, approximately 20% of the entrainment appeared in the drained condensate. At the inlet to the condenser which followed, it was found that no droplets above 70 microns in size remained entrained.

Under certain conditions, arising mainly from parent liquid impurities, a stable layer of foam may form on the liquid surface in evaporators. Entrainment under these conditions will arise entirely from the bursting of bubbles, so that the droplets entrained will be a few microns in size and their total weight much less than under normal boiling conditions. While this layer remains at a given level inside the vapour space, entrainment is reduced. If, however, the

* The British Coal Utilisation Research Association.

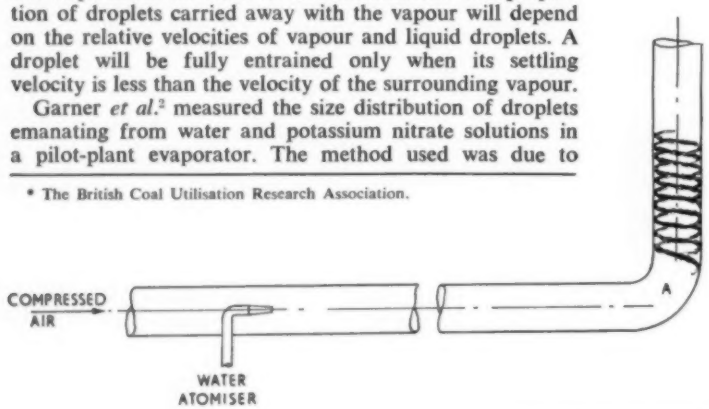

Fig. 1. Sketch of glass pipework used to illustrate swirling velocity of air and atomised water mixtures. The water-flow pattern is in the form of a helix.

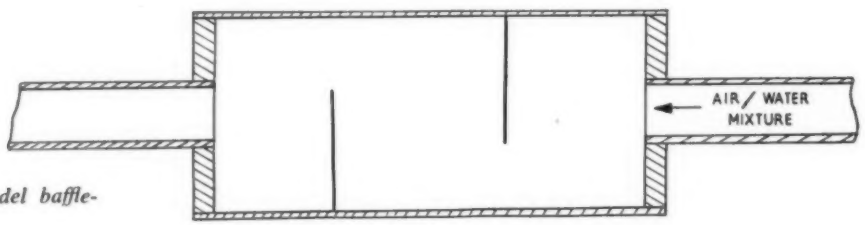

Fig. 2. Sketch of a glass model baffle-type separator.

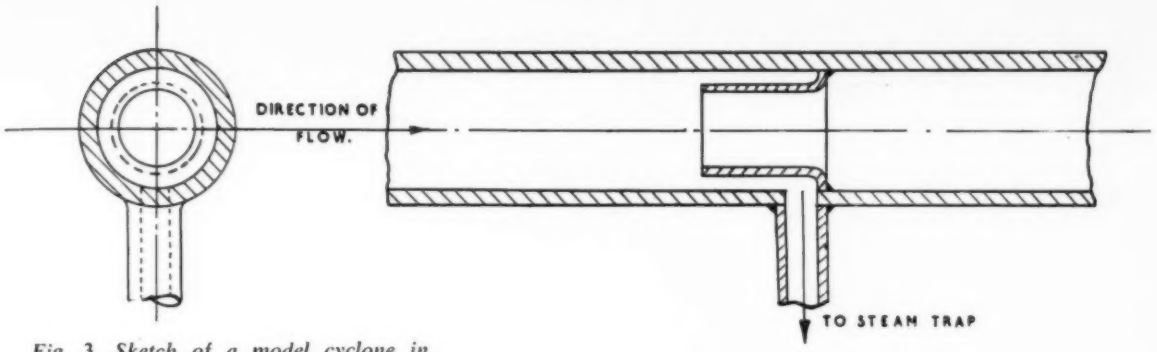

Fig. 3. Sketch of a model cyclone in glass. Note absence of conical section.

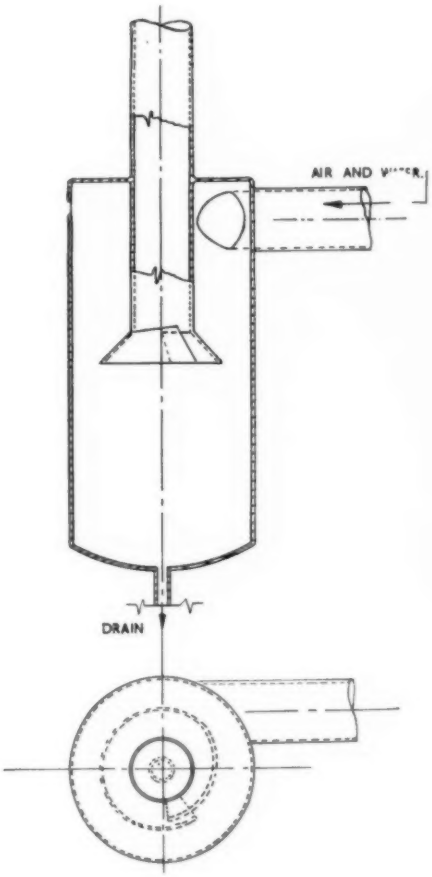

Fig. 4. Cyclone designed to prevent removal of water from offtake.

evaporation rate is raised, it is possible that the upper surface of the foam layer will rise, and eventually fill the vapour space.

Foam will, under these conditions, be carried into the offtake, giving rise to high concentrations of the parent liquid in the vapour produced. This effect was demonstrated in a steam boiler operated at high concentrations of feed-water impurities.[4] The quantity of water carried over was of the order of 25% by weight of the total output. The addition of a suitable antifoam agent collapsed the foam layer and reduced the carry-over to about 1%.

Separation in Pipework

At this point it is useful to consider the degree of separation affected by pipework carrying entrained droplets.

Whytlaw-Gray[5] has shown that when droplets collide they almost invariably form another droplet of larger diameter. There will also be a tendency for condensation to take place on existing droplets, which will again increase their mass. Attempts have been made to express the rate of growth of droplet size during settling for certain very limited conditions by Goldman[6] and Sinclair,[7] who based their work on Einstein's equation of Brownian movement.[8] The equations obtained are highly complex, and no solutions are available for the conditions occurring in industrial pipework.

The process of agglomeration and settling is also accelerated by thermal and acoustic forces. In a thermal gradient, a particle will tend to move towards objects which are colder than its surroundings—for instance, dust near hot bodies will be precipitated and settle on the colder walls of buildings. Sound vibrations above a certain frequency also tend to increase the rate of agglomeration, depending on the size of the particles.

Centrifugal forces are only effective when particles are of comparatively large diameter. The separating velocity of a spherical particle in a centrifugal field is given for the particular size range where Stoke's Law applies by:

$$u = \frac{\omega^2 r D^2(\rho_s - \rho)}{18\eta}$$

where u = separating velocity;
ω = angular velocity;
r = radius of gas path;
D = diameter of particle
ρ_s, ρ = densities of particle and gas respectively; and
η = viscosity of gas.

For a circular gas stream with a 60 ft/sec tangential velocity, Anderson[9] estimates that, as the radius of curvature of the gas stream is reduced from 10 ft to 1.5 in., the separating force increases from 11 to 896 times gravity.

Observations made with glass pipework, arranged as in Fig. 1, which carried air and atomised water, showed that even without creating a tangential velocity artificially, a strong swirling velocity existed. The injected water collected on the walls, particularly after the bend A, and served as a tracer to indicate the air flow.

If liquid droplets are carried by flowing gases in pipes of small diameter, a considerable amount of separation must take place when the droplets have grown to a sufficient mass to be acted upon by these precipitating forces. It is apparent, therefore, that the position of a separator relative to the source of the droplets is an important consideration, for this will govern the droplet size distribution and concentration in the vapour to be treated.

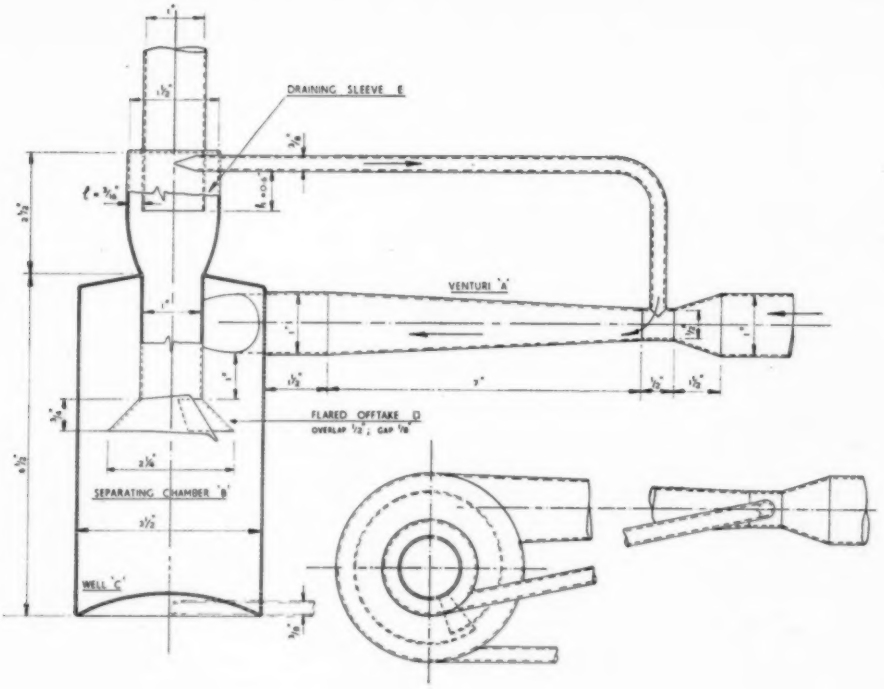

Fig. 5. Final design of cyclone separator (*B.P. App. No.* 9804/54).

Separators and their Development

The foregoing has indicated the difficulties of deducing the true conditions in a system for which a separator has to be designed. While the factors involved are known qualitatively, precise calculations of droplet sizes and distributions at any point in a system are not possible. Various baffle-type separators have been used, but there is little information regarding their performance. Newitt *et al.*[1] included the impact of drops on baffles in their investigations. Information was also obtained concerning the optimum thickness of baffles, the shape of baffle edges and the conditions under which re-entrainment took place.

In the present work using glass models, a typical example of which is shown in Fig. 2, the behaviour of baffles of various kinds on air/water mixtures was observed. At entry velocities typical of industrial steam mains (30 to 100 ft/sec), it was found that the difficulty with such separators was one of collection rather than deposition. While the larger droplets were certainly deposited, they formed films on the baffle surfaces which crept around edges, and subsequently made their way to the walls of the offtake pipe. Considerable expansion of cross-section would therefore be necessary to reduce the velocity sufficiently for efficient collection. It was also found that water already deposited on the inlet pipework was in some cases atomised by impaction on the leading baffle, and re-entrained.

It was apparent, both from experimental work and from theoretical considerations, that at the vapour velocities contemplated the requirements to be fulfilled were:

(a) The separator should provide the means for trapping liquid already deposited on the walls of the entering pipework.

(b) That the vapour velocity should be made use of to remove as much as possible of the liquid remaining entrained in droplet form.

It was considered that a modified form of cyclone separator was necessary to fulfil these requirements.

Most of the published work on cyclones deals with the removal of solid particles from gas streams, and it is possible, when dealing with solids, to verify theoretically derived formulæ by measurements of the particle-size distributions at various points in the system. Various formulæ of the following type[10] have been developed for the smallest size of particle to be almost completely removed in a given apparatus.

$$D_{\min.} = \frac{9\eta b}{\pi N V(\rho_s - \rho)}$$

where N = number of revolutions made by the gas stream in the apparatus;
b = width of gas stream;
ρ_s = density of solid particle;
ρ = density of gas;
V = tangential velocity; and
η = gas viscosity.

Such formulæ usually assume no agglomeration and no re-entrainment, which probably accounts for the fact that it is always necessary to determine the ultimate performance of a particular design by measurement. For the removal of liquid droplets, it is probable that, due to coagulation, the efficiencies will be somewhat higher than those predicted for solids, provided that re-entrainment and creep of films are kept low by careful design.

Cyclone dimensions have been suggested by Ter Linden,[11] who considered the shape of the inlet, the depth of the outlet duct below the top, the ratio of cyclone diameter to outlet diameter and the height of the cyclone. Stairmand[12] and Lapple[13] have given certain tentative correction factors where scaling-up of cyclone sizes is neces-

sary for geometrically similar models. Stairmand, however, considers that an experimental check on performance is necessary if large changes in size are undertaken. Lapple[14] states that there is little evidence to justify the use of the long cone which Stairmand considers essential for high performance.

Where the removal of liquids by cyclones is contemplated, two design factors have to be taken into account which do not apply to solid particles. These are as follows:

(1) The gas velocity near the walls must be restricted so that the shearing force on the liquid films adhering to the walls does not cause re-entrainment.

(2) Secondary flows in the upper portion of the cyclone may cause superficial liquid films to creep into the offtake.

Based on the available information concerning cyclone design, a model cyclone was constructed in glass, as shown in Fig. 3. This did not include a conical base, but the flared offtake was an attempt to prevent the entry of creeping liquid films into the offtake. Water was introduced into the entering air stream by means of an atomiser. Droplets produced by atomisers are, in general, larger than those occurring naturally in wet steam. The object of the glass model, however, was to observe the behaviour of surface films, and not to try to simulate the behaviour of the entrained droplets.

At entry velocities of 30 to 100 ft/sec certain effects were noted. Firstly, water films did, in fact, creep over the upper portion of the cyclone chamber, and while some of the water was thrown off at the broken flare, the greater part crept around the flare and into the offtake pipe. Various changes in offtake design failed to overcome this source of inefficiency. Secondly, the swirling well which formed in the bottom of the cyclone tended to splash water into the body of the cyclone, and this water was re-entrained. Various changes in design were made to the cyclone base, and it was found that the angle of splash could be widened by using a concave base section with a tangential water offtake. Thus any splashing which occurred was directed to the walls of the cyclone chamber, and thence back to the well.

Having failed to cure the creep of liquid films into the cyclone offtake, attention was then given to the removal of the water from the offtake itself. A sleeve was constructed in the glass pipe, as shown in Fig. 4, for removal of the surface moisture. Despite various experimental changes in the dimensions, it was found to be impossible to drain this sleeve without also drawing off some air with the water. It was essential, therefore, to incorporate in the cyclone design a means of leading the outlet from such a sleeve to a point of lower pressure in the system. This was effected by making the inlet to the cyclone in the form of a venturi, and connecting the sleeve to its throat, the outlet from the sleeve being tangential. This was found to give sufficient return flow to drain the sleeve effectively. The optimum dimensions and position of the sleeve were found by trial and error and another glass model cyclone was constructed incorporating these modifications (see Fig. 5). It was then considered that the cyclone itself removed entrained droplets efficiently, and the difficulties associated with creeping and splashing had been overcome. The tangential velocities at the cyclone walls were also kept below the critical values recommended by Stairmand,[15] who considered that the value of ρU^2_w, which is proportional to the shearing force, should not exceed 20,000 for cyclones dealing with water droplets, or 40,000 for cyclones removing oil mists (ρ=kg/m^3, U_w in ft/sec). This was made easier by using the cylindrical chamber rather than a long cone.

A prototype separator (British Patent Application No. 9804/54) was therefore made up in metal suitable to withstand a pressure of 100 lb/sq. in., and a rig was constructed to assess its efficiency over a range of steam velocities and quantities of water handled. A simplified drawing of this apparatus is shown in Fig. 6. Values of water per pound of steam of 0.05 to 0.25 were obtained by varying the number of cooling sections in the line. Complete heat balances were then carried out on the condenser, and the condensate and the water removed by the separator were measured. At a steam pressure of 50 lb/sq. in. it was possible to establish an efficiency curve for the separator over a range of steam velocities. This curve is shown in Fig. 7. The quantity of water handled did not appear to affect the efficiency at any given velocity. Within the range covered, therefore, the efficiency appeared to be independent of the concentration of water carried. In carrying out heat balances of this kind, however, there are variable factors, such as surging in the condenser, which tend to make reproduceability difficult. The efficiency curve was based on an average of about ten tests at each velocity stage. The evidence of the glass model tests indicated that the drop of efficiency above 90 ft/sec was due to the failure of the sleeve to handle the superficial water in the offtake, and not due to re-entrainment by shear at the walls of the main chamber, or pick-up from the base. Thus reduction in diameter at the venturi throat would increase the velocity range of the separator at the expense of the overall pressure drop. The pressure drop through the separator over the range of velocities used is shown in the accompanying graph, Fig. 8 (see p. 184).

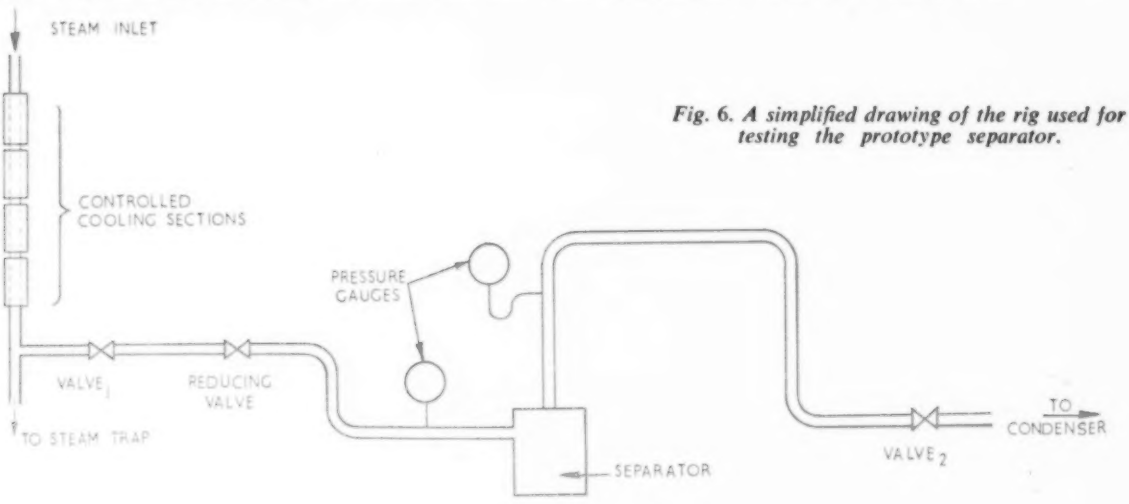

Fig. 6. A simplified drawing of the rig used for testing the prototype separator.

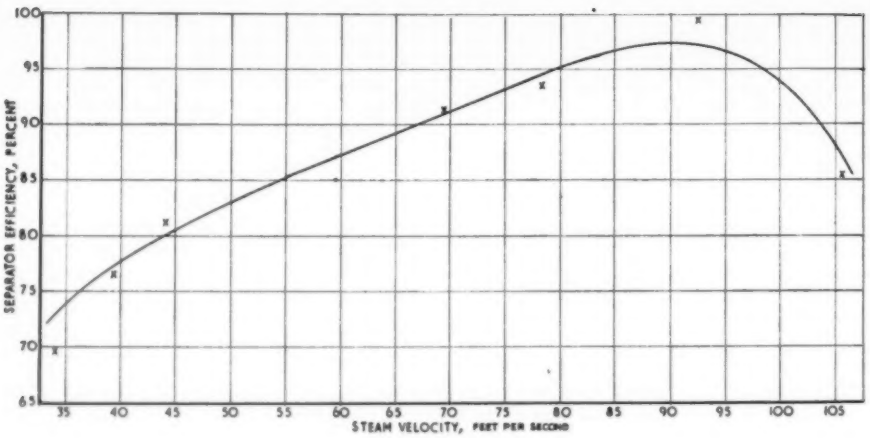

Fig. 7. Efficiency curve of final design of separator.

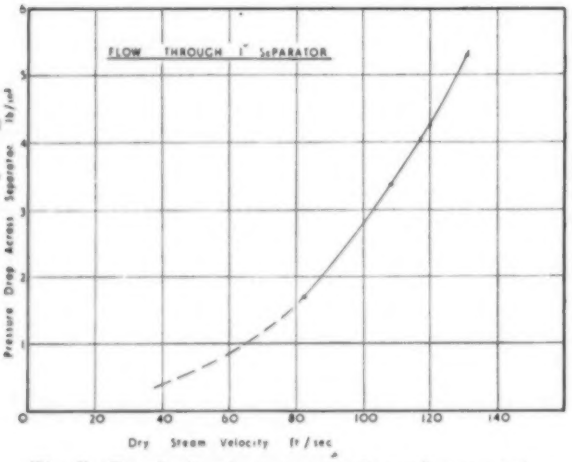

Fig. 8. Graph showing pressure-drop characteristics of the final design of separator.

Conclusions

The development of a cyclone separator for the separation of water from steam has been outlined. Investigations were concentrated on the known faults of cyclones when handling gas/liquid mixtures. In this particular case, glass models were found to be invaluable as a method of obtaining practical answers quickly and cheaply, and wider use of such visual techniques is strongly advocated wherever separator design is contemplated. This is particularly the case when factors such as line deposition and coagulation make a mathematical estimate of conditions at the separator inlet difficult. The efficiency of the separator lies between 70 and 95% over a fairly wide velocity range, and it is considered that the performance is superior to existing baffle-type separators.

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The authors' thanks are due to Mr. N. Marshall who assisted in the design of the separator, and to the Glass Blowing Department of B.C.U.R.A. for the construction of numerous models. Our thanks are also due to the Director-General of B.C.U.R.A., Dr. D. T. A. Townend, for permission to publish this article.

Completely New Type of Powder Classifier

AFTER a ten-year research programme, Sharples Centrifuges Ltd., of Tower House, Stroud, Gloucestershire, announce their new super classifier. This equipment is claimed to be an ideal air-vortex-type classifier.

In the field of dry classification, or the division of powdered materials into fractions according to particle size, there are three factors of vital interest to the chemical, minerals, metals and other industries. These are cutpoint—the particle size about which the powder is divided; product recovery (yield)—that portion of the product available in the feed which is separated by the classifier (the efficiency of the classifier will determine the degree of product recovery); and capacity—the rated throughput.

The cutpoint of the Super Classifier is said to be exceedingly precise. For example, it is claimed that fine fractions with a top size in the range of 15-20 microns will contain less than 0.01-0.04% 325-mesh screen residue, while the cutpoint sharpness is not affected by throughput rate or size distribution of the feed. Product recovery, or yield, of the Super Classifier is said to be very high, varying from 80% to well over 90%, depending upon product requirements. Production runs on talc have been made with over 97% yield at a top-size cutpoint of about 15 microns. As with cutpoint, the manufacturers say the efficiency of the Super Classifier is not affected by changes in throughput rate or size distribution of the feed.

Because the cutpoint and efficiency of the Super Classifier are not affected by the feed rate or distribution, high production capacities combined with high-quality product are said to be easily maintained. With such high efficiencies, the circulating load on existing grinder systems is greatly reduced, and this makes possible an increase in product output without additional grinder capacity.

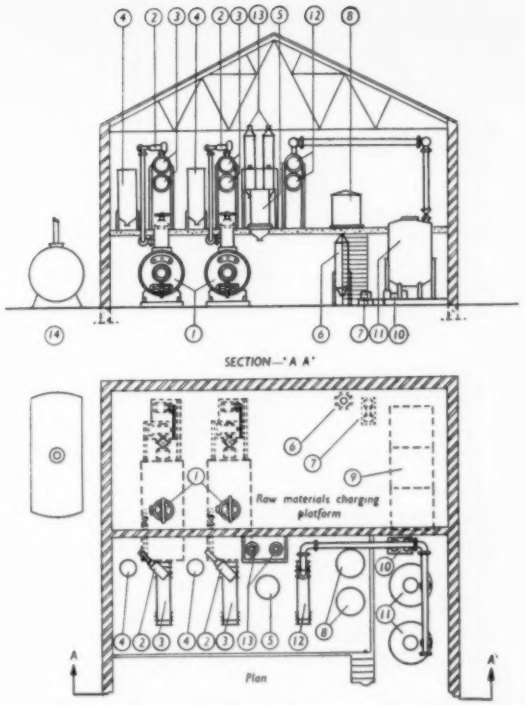
The Super Classifier operates continuously without adjustment, and an absolute minimum of operator attention is required. To change from one cutpoint to another is a simple matter, requiring only the changing of two vane rings and a drive pulley.

NEW SOLVENT EXTRACTION PLANT

INFORMATION on the first British prototype dehydrating and degreasing solvent extraction plant, designed by Iwel Ltd., of London, and using the Wacher-Chemie patented process, has recently been released. The plant is intended for the treatment of raw animal wastes, although, the manufacturers state, it also has applications outside the field of animal by-products, as, for example, the recovery of palm oil from tin-plate waste and paraffin wax from waste paper.

The prototype has been in use in a North of England factory since April, 1956, and has fully justified Iwel's claims; one of which is that their equipment will give a higher tallow output than existing plant. Two other important advantages claimed for the equipment are the elimination both of intermediate handling and of all offensive smells normally associated with the cooking and extraction processes.

Raw animal by-products contain by weight approximately 15-20% tallow fat. Cooked and mechanically extracted, the residues contain by weight approximately 9-12% fat (the balance having separated as liquid). Using the solvent extraction process, however, the residues contain by weight only about 4% fat. This means that approximately 5-8% more fat is available at prices ranging from £70-£75 per ton instead of being sold as part of the meal at £28-£30 per ton. By extracting a higher percentage of fat, the protein content and keeping qualities of the meal are improved and the grinding, screening and sacking processes are made easier. The solvent used in this plant is perchlorethylene (C_2Cl_4), which is a non-inflammable hydrocarbon solvent.



Layout of typical combined dehydrating and degreasing plant. (1) *Combined cookers and extractors.* (2) *Horizontal vapour strainers.* (3) *Combined condenser coolers.* (4) *Vertical automatic hot and cold.* (5) *Separators.* (6) *Tubular solvent preheater.* (7) *Horizontal solvent miscella pump.* (8) *Miscella filters.* (9) *Rectangular miscella wash tank.* (10) *Horizontal filtered miscella pump.* (11) *Vertical stills.* (12) *Combined condenser cooler stills.* (13) *Twin spray vapour recovery unit.* (14) *Horizontal solvent storage tank.*

The Process Stages

The material used is raw animal carcass, offals and other slaughter-house waste, including preferably not less than 20% by weight of bone. The process consists of seven main stages:

(1) Charging the raw animal material into the extractors, venting until the material is heated.

(2) Raising and sustaining pressure, as may be required.

(3) Drawing off pre-cook fat and pumping in solvent.

(4) Drawing off miscella.

(5) Filtration and distillation of miscella.

(6) Washing and drying residue material in extractors.

(7) Discharging the finished meal.

When the solvent is pumped in, the boiling point drops considerably and azeotropic distillation is established. A considerable increase in volume of water vapour takes place with the reduction of the boiling point of the combined water and solvent. The ratio of perchlorethylene to water (3 : 1) will produce a boiling range of from 185°F (85°C) to 212°F (100°C), according to the amount of water present in the miscella. Towards the end of the degreasing stage, the vapour temperature rises above 212°F (100°C) as the moisture content is lowered, and at 221°F (105°C), all moisture having been eliminated, the machine is shut down and jacket steam cut off. The material is then allowed a short settling period and after 5-10 minutes the strong miscella is drawn off. The miscella should be allowed to settle out in a separate vessel for a period of about 20 minutes before filtration is commenced.

The mixed solvent and water vapours produced are condensed in a tubular-type condenser. This condenser performs two specific functions: (a) it condenses the steam and solvent vapours from the extractors, so giving a vacuum effect between the extractor and the solvent separating system; and (b) it cools the condense (before it passes into the solvent separators) to such a temperature that maximum separation is possible.

Tallow produced with this plant is of clean, bleachable quality and high titre with lower free fatty acid than can normally be obtained without deodorisation treatment.

Improved Solvent Extraction Plant

Iwel have also designed an improved solvent extraction plant to treat previously-cooked greaves for the production of low oil-content meals of high protein value and good keeping quality. Economical operation is the chief feature claimed for this new plant, which is designed for users of existing rendering plant. The solvent used is a fractional petroleum spirit chosen for its penetrative powers, ease of handling and availability (not subject to rationing under existing restrictions). Alternative chlorine solvents can be used if preferred.

The solvent extractor has several important features, one being a special filter floor, which ensures speedy operation. This plant has an output of over a ton an hour, and is suitable for use with rendering plants and melters employed in the manufacture of high-quality meals. It extracts down to a residual fat content of 2-4% as required. The plant is designed in various sizes to meet all capacities and can be used with all oil-bearing materials. A distillation unit is embodied for the recovery of the solvent from the end products; overall solvent loss is claimed to be not more than 0.8% by weight of the raw materials treated. The unit embodies a high-speed circulating heater, which obviates burning or deterioration of the tallow.

Fig. 1. Spontaneous brittle fracture along the web of a joist. The free curvature denotes a previous state of severe residual stress. The fracture illustrated originated from a fabrication notch.

BRITTLE FRACTURE:

A HAZARD IN CHEMICAL PLANT

This article describes the conditions which give rise to brittle fracture failures and discusses practical precautionary measures

A. A. WELLS

B.Sc. (Eng.), Ph.D.*

ALTHOUGH chemical engineers may not have first-hand experience of brittle fracture, the very destructiveness of this mode of failure establishes its importance for consideration together with other kinds, such as corrosion, creep and fatigue.

One casualty example of interest relates to two oil storage tanks at Fawley[1]. These were of low-carbon mild steel to B.S.15, welded, of dimensions and specification conforming to Code 12C of the American Petroleum Industry and Code 709 of Standard Oil Developments. Each tank was about 140 ft in diameter × 54 ft high with nine strakes of plating ranging from $1\frac{3}{32}$ in. at the base to $\frac{1}{4}$-in. thickness at the top. In the tanks the bottom plating was comparatively thin and rested directly on a prepared soil foundation. The stress distribution in the cylindrical shells was simple circumferential tension, coupled with minor local bending stresses between strakes, and when full of water for hydrostatic test the maximum tensile hoop stress was no more than 8 tons/sq. in.

That two such tanks should fracture completely from bottom to top while being water-tested prior to service was, to say the least, curious. Later examination of fractured surfaces showed an almost complete absence of prior deformation in the lower strakes in contrast with ductile fractures in the thin material above. As shown by distinctive fracture markings, both fractures commenced at transverse weld cavities or cracks associated with the circumferential welds. Although originating in these zones, the fractures subsequently showed no tendency to follow the welded joints preferentially to the parent material. A notable feature of both fractures was their occurrence when the tanks were about half full of water, so that stresses were by no means excessive; nor was there any indication of failure as a consequence of impact. Such fractures of oil storage tanks have not been uncommon, and a number of similar cases from other parts of the world have been described by Shank.[2] A recent computation has suggested that the rate of occurrence has been between 0.1 and 1 a year per million tons of steel embodied in the known tank population.

The simple casualty example shown in Fig. 1 occurred quite spontaneously with no external load, and is of great interest purely from this point of view. The absence of deformation distinguishes it as of the brittle type, and the chevron pattern which could be observed on this fracture, as on most others, showed that it originated at a notch, gas cut into the web at one end. The opposite curvatures of the separated halves give some idea as to the state of residual stress, tensile in the flanges and compressive in the web, which must have existed prior to fracture. From this it must be concluded that such stresses, where they exist, must provide the same type of motive force in brittle fractures as those resulting from external loads.

Pressure vessels produced by welding under shop conditions do not seem to have been subject to extensive fractures, except during fabrication or when associated in service with severe differential heating and cooling. Moreover, in site-welded vessels incorporating steel plates of $\frac{1}{2}$-in. thickness or less, brittle fractures have been much less frequent. This is underlined in the behaviour of the fractured oil storage tanks where, as has been mentioned, the upper strakes of plating failed by tearing apart in the ductile manner after extensive deformation, in contrast to the brittle failure of the lower and thicker strakes.

It will be useful to consider here the causes underlying these two kinds of fracture. Additionally, it is important to assess the relative tendencies of riveted and welded

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structures to this type of fracture, and to observe the influence of temperature, since so many fractures have occurred under cold climatic conditions. On the first of these points it is notable that Shank describes fractures in riveted structures which have occurred within the past hundred years, but is unable to decide, on the inadequate evidence for statistical examination; the incidence in welded structures recently has been significantly different.

Temperature has proved to be of such importance in brittle fracture studies that a detailed discussion is essential. Most of the essential features of brittle and ductile fracturing in low-carbon steel may be demonstrated in laboratory tests with notched bars, and this also has been known for nearly a century. However, it should be noted that the brittle mode is rarely observed in specimens, except at very low temperatures, without some prior notch effect. In particular, the plain tensile test, on which the mechanical properties of steels are mainly assessed, often conceals a propensity towards brittle fracture.

The Transition Temperature

Notched bar tests are of many different kinds, but all are able to show the phenomenon of the temperature transition in low-carbon steels. Tests associated with casualty material frequently place this transition within the atmospheric temperature range. At temperatures above the transition, in spite of the presence of the notch, the fracture is ductile, as in the plain tensile test. At temperatures below the transition, the deformation before fracture becames progressively less and the surface appearance changes to that of a granular crystalline aggregate like that of cube sugar. Similarly, the bright cleavage facets distinguish the fracture from other types due to fatigue, corrosion cracking or creep. On closer examination it is seen that the facets expose consistent but different crystal planes from those produced by shear. However, a fully-brittle fracture reveals these facets, strongly interspersed with crystals, failing in the shear mode. Thus notch brittle steel is not fully brittle in the same sense as glass. The dual-fracture mode is characteristic of the body-centred cubic crystallographic structure of ferrite, but cleavage may also be observed in hexagonal metals, although not in those with the face-centred cubic lattice, e.g., aluminium.

The change of prefracture deformation, together with change of fracture appearance, enables transition temperature tests to be divided into two classes. Another test arises from the observation that running brittle-cracks are not always arrested at the same temperatures as those at which they are initiated. The three tests which have been chosen for illustration in Fig. 2 are generally representative of the three types, and all three are used in this country. However, any survey of this subject must be arbitrary, as many other test procedures exist.

Variants of the notched bend impact test, on specimens about 1 cm sq., have been used for half a centrury, but the Charpy *v*-notch test, whose specimen and manner of support are shown in Fig. 2, is now of considerable importance owing to its wide international use. In the test, the specimen is broken by the impact of a pendulum, and the difference between heights of rise before and after impact allows fracture energy absorption to be determined. The point supports of the specimen permit good temperature control. The small size of the specimen also facilitates comparisons through a wide range of thicknesses and sections in one testing machine, whereby metallurgical influences such as those arising in steel manufacture may be singled out. Transition temperatures may be assessed on the basis of energy absorption or fracture appearance in the Charpy *v*-test. Energy absorption is frequently associated with a definite figure sometimes placed at 15 ft lb., and the fracture appearance with a definite projected area of crystallinity in the fracture surface, often 75%.

Of the fracture appearance tests, the Tipper notch tensile test is one of the most decisive in its assessment of transition temperature, being subject to much smaller scatter than most impact tests with smaller specimens. Used mainly with plate material, it caters for a full range of thicknesses, and widths at least two and a half times as great, but always with symmetrical notch pairs each $\frac{1}{8}$ in. deep (Fig. 2). Each specimen is extended slowly to fracture in a tensile machine, being allowed to approach testing temperature in the grips after prior cooling or warming. Thermocouples are used for estimating temperature at the moment of fracture. Although 50% of crystallinity in the projected area of fracture is usually used as a brittleness criterion, the temperature transition is frequently so sharp that the region from 10% to 90% crystallinity is contained within a space of $\pm$ 2°C. Since quite large loads may be needed to break specimens from thick material in tension, a slow notched-bend test with an equally large specimen is sometimes employed as a convenient alternative.

The Robertson crack-arrest test arose from a recognition that temperature conditions for the running and arrest of brittle cracks are not always the same as for their commencement at a notch. This test concentrates attention on the temperature conditions. The test-piece of full thickness (Fig. 2) is 8 in. or more wide and, although fairly short, is

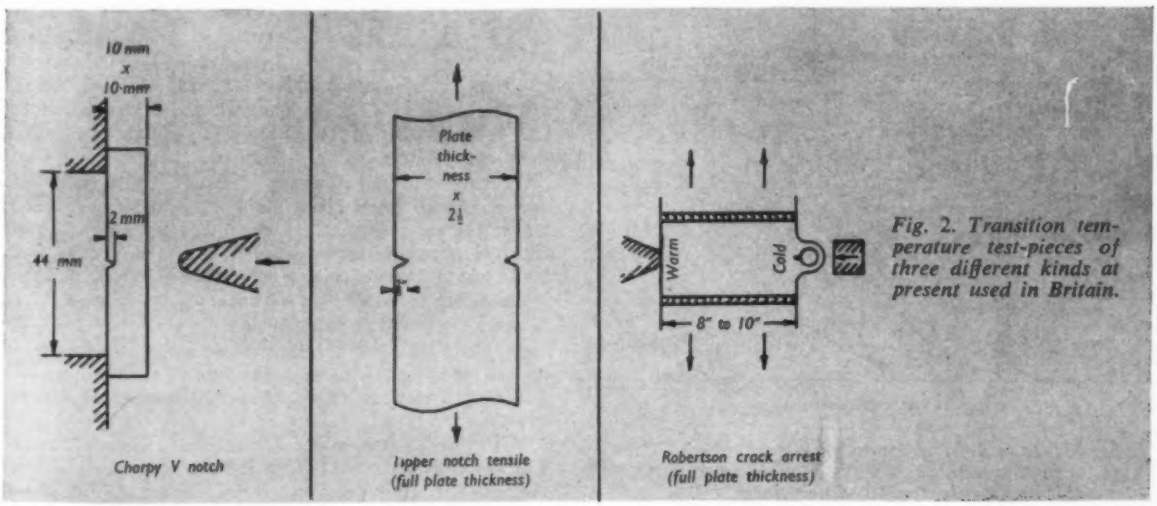

Fig. 2. Transition temperature test-pieces of three different kinds at present used in Britain.

welded into end connections by means of which a steady tension may be exerted. The sawcut notch on one side of the specimen is associated with a knob which is struck a blow from a bolt gun at the moment of test. The momentum from the blow causes partial plastic collapse of the knob, with a resultant wedging action at the notch. Transverse bending of the specimen in its own plane, arising from the blow, is suppressed by the heavy mass in contact on the side of the specimen opposite the knob. Prior to test, the inner periphery of the knob is cooled with liquid nitrogen and the further side warmed with a small flame. In this way, not only may the fracture be easily started, but a temperature gradient is also induced along which the fracture progresses until arrested. The temperature at the end of the crack on the surface is then measured and becomes the crack-arrest temperature.

These three groups of test do not always yield indentical transition temperatures for given steels, even when test-pieces are each cut from the same plate. The variation may be sufficiently systematic, as shown in Fig. 3 for three different steel types, to indicate that slightly different properties are being measured in each test. Nevertheless, the different tests, with some exceptions, will often group different steels in the same order of transition temperature, as also shown in Fig. 3. Similarly, it may be noted from this figure that some of the steels, when rolled to 1-in. thickness, possess transition temperatures in the atmospheric range. The minor differences shown by different tests assume an importance which would not exist if all the values were well below 0°C. The difficulty of deciding upon one particular test for steel specification is thus emphasised, and it appears to be necessary, therefore, to calibrate tests on particular steels against experience both with casualties and with more realistic structural tests.

Manufacture and Transition Temperatures

The Charpy *v*-test has been much used in assessing variations of transition temperature introduced with different steel-making techniques. In particular, the examination of both casualties and laboratory tests has confirmed that thick plates show higher transition temperatures and greater tendency to fracture than thin ones. Further, this effect has been shown to be mainly metallurgical in character, since it may be demonstrated even with identically-dimensioned Charpy test-pieces. It is also accompanied by grain-size variations, in that coarser structures appear in thicker plates and sections. The results of a systematic rolling-mill investigation conducted by Mackenzie[3] have shown conclusively that these differences

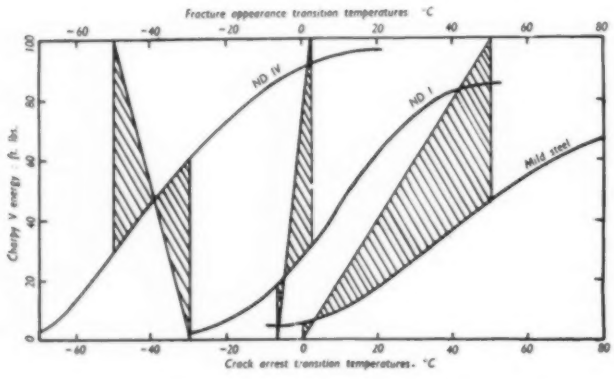

Fig. 3. Transition temperature data for 1-in. thick plates in three low-carbon steels of different, but not necessarily typical, notch ductilities.

appear in the later stages of rolling. The thicker plates from a given sized ingot, by suffering less hot deformation, emerge from the rolls at a higher temperature and cool more slowly. In this way, a plate 1½ in. thick may have a transition temperature 40°C higher than a ½-in. thick plate. The effect may be reduced if plates are later subject to a normalising treatment, in which the grain structure is refined. But difficulties still arise with very thick material in securing a sufficiently large cooling rate through temperature regions at which grain coarsening may occur following this operation.

It was shown by Barr and Honeyman[4] in 1947 that the adverse effect of carbon on transition temperature may be balanced by the opposite effect of correct additions of manganese. Thus a high manganese-to-carbon ratio has a beneficial effect to the extent of nearly 10°C drop of transition temperature for every unit increase in the ratio. If manganese additions are too large, however, the steel becomes hardenable and subject to heat-affected zone cracking when welded without special precautions. For the maintenance of the strength of steel there is a lower limit to the carbon content of the metal. The carbon additions which result from adding manganese in the form of ferro-manganese must also be limited. In spite of these limits, a trend has emerged towards the use of steels with about 1% manganese and less than 0.2% carbon, and this has allowed a significant improvement in notch ductilities without serious modification of the manufacturing process.

Lower transition temperatures may be achieved by grain control of the steel, using small additions of aluminium or silicon. Such steels, known as "fully-killed", have a much finer grain structure, but suffer from greater shrinkage during solidification of the ingot. The irregular shrinkage cavity must be removed by extensive cropping of each ingot, and the resultant waste renders the steel more expensive. In the thicker plates the best use of grain refinement can only be made if it is combined with subsequent normalising, to reduce any effects of coarsening in the hot-working cycle.

It is noteworthy that procedures for depressing low-carbon-steel transition temperatures may sometimes impair high-temperature creep resistance. Thus some compromise may be required for constructions that have to operate over a wide range of temperature.

Procedures for avoiding brittle fracture in some ferritic low-alloy steels from which vessels are fabricated by welding have been described in papers at a recent conference.[5] In particular, it appears that sub-zero (Centigrade) transition temperatures may be achieved with some alloy steels, even in quite large thicknesses. The following are some of the examples discussed:

(*a*) Mn-Cr-Mo-V (Colvilles Ducol W.30: air hardening). In thicknesses up to 5 in. when preheat of the order of 200°C is employed to avoid cracking from welding, and this is followed by a tempering and stress-relieving heat treatment at approximately 650°C. (27 tons/sq. in. yield and 38 tons/sq. in. ultimate strength.)

(b) Mn-Ni-Cr-Mo plus other elements (U.S. Steel T.1.: quenched and tempered). In thicknesses up to 2 in. without preheating or post-heating when welded. High strengths and low transition temperatures are characteristic of this steel, which is quenched and tempered when produced. (40 tons/sq. in. yield and 47 tons/sq. in. ultimate tensile strength (miniumum values).)

(*c*) Mo-B (United Steels Fortiweld). In thicknesses up to 1 in. and more, without preheating or post-heating when welded. (32 tons/sq. in. yield and 40 tons/sq. in. ultimate strength.)

With low-carbon steels the need to secure adequate fracture resistance has led, in Britain, to a draft Standard specification, supplementing B.S.S. 13 and 15 by embodi-

ment of a notch ductility (ND) test. The four ND grades are typified by adequate energy absorption in the Charpy v-notch test at a specified temperature. Two of the steels, for which Charpy curves are given in Fig. 3, have been allocated ND numbers relative to their specification levels.

Wide-plate Tests

As mentioned above, some calibration of laboratory transition temperature tests is inevitable if the results are to correlate with casualty experience. In this respect, much useful information has been collected by classification societies, insurance companies and other bodies. On the other hand, information on temperature, stress and other conditions at the time of casualty is not always unambiguous. Moreover, there will be no records to assist in assessing new materials. In such circumstances structural testing on a large scale is desirable, and much of this has been performed with wide plates. At the conclusion of World War II, many test results with notched steel specimens up to 6 ft and even 8 ft wide and $\frac{1}{4}$ in. thick were produced in the U.S.A., and, subsequently, in Europe. Such tests have not only been concerned with material transition temperatures, but also with strengths under brittle conditions, and with typical crack-starting flaws.

Some features of wide-plate tests are described below:

Wide plates strained at temperatures below the brittle temperature (in the presence only of a mechanical notch effect) always appear to withstand loads above those for full yield before brittle fracture occurs. This feature is of importance, since it distinguishes their behaviour from that of some casualties where stress conditions at the time of failure may be quite low. In many tests of this nature, the mechanical notch took the form of a transverse sawn-slit in each plate, and the ends of the slit were cut with a jeweller's saw to considerable sharpness. Subsequent experiments have also been performed with the ends of the slit extended by natural cracking. In spite of this procedure the need for full yield to precede fracture remained unchanged. It was therefore concluded that an initiation barrier must be overcome before a fast-running brittle crack may be propagated in low-carbon steel-plate. Since the onset of full yield in a plate, where the yield zones embrace the notch root, is accompanied by a progressive increase of the order of 10^2 or more of the plastic strain at the root, it appears that initiation of fracture in this way is closely connected with extensive work hardening. The reasons for this are still not fully understood, but it is easy to link the event with many cases of brittle fractures initiated from cold sheared and punched edges when riveted constructions were more common than welded. Cold-forming operations of this nature also produced severe local work hardening.

Wide-plate tests have also demonstrated that welded joints free from major flaws do not fail in the brittle manner when under load, irrespective of the temperature of test—subject to the reservation that geometrical discontinuities are not introduced. For instance, tensile tests on welded structural components such as ship hatch-corner models produced brittle fractures below the transition temperature after full yield had taken place, even with welded joints free from flaws. The notch effects, however, had already been incorporated by design.

Tests on wide plates incorporating welded butt-joints, together with deliberately introduced flaws have resulted in brittle failure at low applied-stress levels, much as in the storage-tank casualties previously mentioned. But it is necessary to perform a tensile test of this type with the butt weld parallel to the line of pull, as in Fig. 4. Further, it is also necessary to introduce the simulated flaws so that they are present during the welding operation, and not just at the time of testing. The manner of introduction of an artificial flaw by means of jeweller's saw-cuts in the edges prepared for welding is also shown in Fig. 4. Each saw-cut is made just sufficiently deep to avoid its elimination through fusion during the welding operation.

A tensile test rig of 700 tons capacity with which many welded plates 36 in. square and 1 in. thick have been strained to failure at the author's laboratory is shown in Fig. 5. Each test plate is attached by welding to heavy steel ends, and the loads are induced between the end attachments through four identical hydraulic capsules, each connected to a compression bar. The plates may be cooled to any desired temperature above $-60°C$ by means of direct contact with solid carbon dioxide. Arrangements also exist whereby autographic measurements of load and extension may be made, and for the absorption of the energy of the assembly at the moment of fracture.

With a number of specimens from any given steel, the fractures differ in character depending upon the temperature.[6, 7] There is, for instance, little point in conducting tests much above the transition temperature at which the

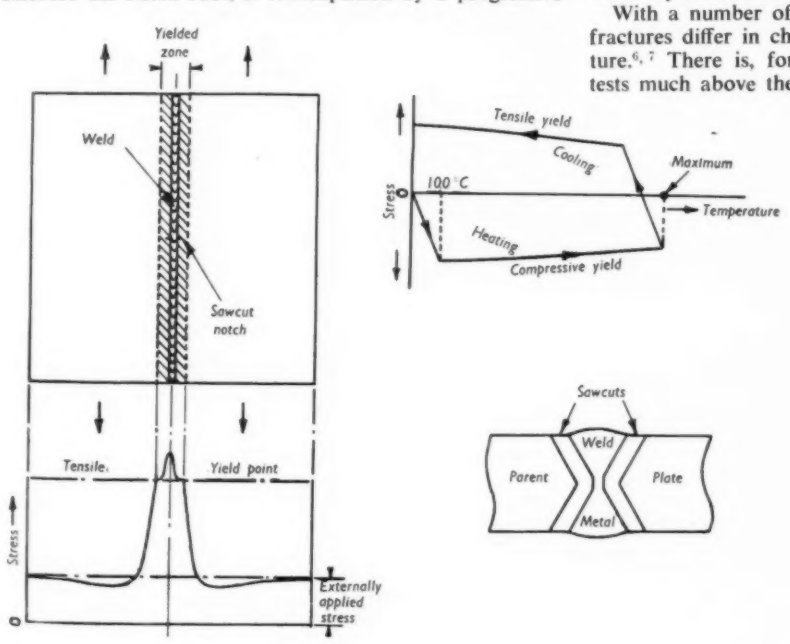

Fig. 4. Residual stress and plastic strain distributions induced by restraint and the temperature cycle near a butt weld joining two wide plates. The saw-cut notch simulating a weld flaw, by means of which low stress fracture of the assembly may be obtained in a tensile test, is also shown.

fracture appears. Even somewhat below such a temperature, yield-point brittle fractures are experienced. As testing temperatures descend again, there occur first through fractures from the notch roots at stress levels well below the yield point. Then follow short fractures arrested at positions a few inches away on both sides of each weld. After the occurrence of short fractures, reinitiation demands the application of tensile loads sufficient to yield each remaining area of cross-section, as with unwelded plates. This behaviour with varying temperature is plotted in Fig. 6. In this figure the average applied tensile stress at fracture with different severities of artificial (saw-cut) flaw is shown by a shaded band, and, in practice, the spread of results arises because the control of severity is incomplete. The division of the results as between short and through fractures is much as predicted by a crack-arrest test of the Robertson type, and a typical curve is superimposed.

Complex behaviour of this kind may only be explained if the thermal effects of welding are taken into account. With a sufficiently large plate, the main body not only remains fairly cool during the whole welding operation, but is also relatively rigid. In consequence, longitudinal thermal movements of the weld metal and heat-affected zone are almost completely restrained. The resultant stress variations during heating and cooling are shown in Fig. 4, with elastic followed by plastic compression during heating to the maximum temperature. During cooling there is elastic recovery followed by elastic and then plastic tensile strain. For any cycle whose peak temperature approaches melting point, at which temperature nearly all stresses are thermally relaxed, the material sustains the equivalent of almost 2% plastic tensile strain during cooling to room temperature. If a notch is present during the occurrence of these events, a concentration of plastic strain and work-hardening appears at the root by the time cooling is complete, and before external loading is even commenced. In this way, premature fracture initiations may be accounted for. In addition, it appears that the combination of plastic strain and raised temperature also has a strain ageing and further embrittling effect. The latter may be observed in terms of higher transition temperatures in portions of the heat-affected zone from which Charpy specimens are extracted.

The plastic strain arising during cooling also leaves the material adjacent to the weld in a state of yield-point tensile stress when cooling after welding is complete. A typical distribution of induced residual stresses with superimposed tensile stresses from external load is shown in Fig. 4. The existence of the residual tensile-stress system enables the mechanism of crack arrest to be qualitatively understood where short fracture occurs, since crack arrest follows naturally where the crack runs into a sufficiently diminished stress field. On the other hand, there is little experimental evidence to suggest that any crack may be permitted to start under a condition of relaxed elastic stress, even where a high degree of plastic work has previously been sustained at the original notch root. Thus high-elastic stress at fracture commencement, as well as high previous plastic strain, must be regarded as an essential adjunct to fracture, and this has been the subject of much research leading to the conclusion that, as for a Griffith-type crack, the minimum stress in an undisturbed field in which a crack is to run is inversely proportional to the square root of the original crack length. It is, therefore, at least of yield-point value for any crack contained within a weld of normal proportions.[6, 7]

The crucial test of the hypotheses above is to examine the behaviour of modified test-pieces in which (*a*) the residual stresses alone have been removed and (*b*) the plastic movements arising during welding have been

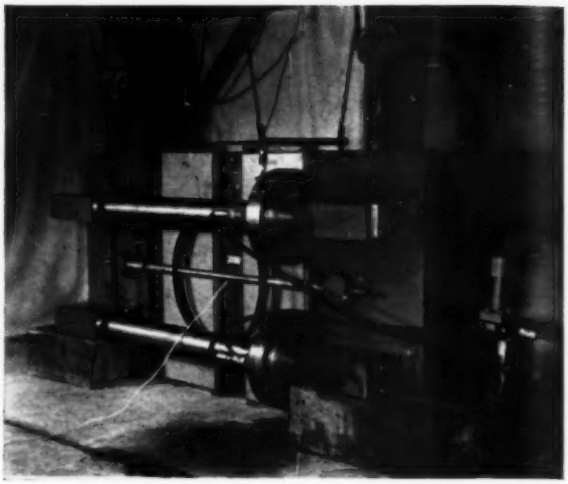

Fig. 5. A tensile testing rig of 700 tons capacity, by means of which brittle fractures may be produced in plates of 36 in. × 1 in. cross-section at temperatures down to −60°C.

neutralised. In (*a*), the desired condition may be achieved by a mechanical stress relief, in which the prepared specimen is externally loaded to the yield point at a temperature just sufficiently high to ensure completely ductile behaviour without cracking. When the load is released it may be shown that sufficient localised plastic flow has taken place for the longitudinal residual stresses to be removed. Tests of such specimens, even at quite low temperatures, show that no brittle failure may occur at less than the yield point of externally applied stress. This is shown in Fig. 7. In (*b*) furnace heat-treatment at 650°C for low carbon steel-plates not only ensures the removal of residual stresses but also softens previously work-hardened zones. Furthermore, the cooling of the uniformly heated plate does not introduce further residual strains. The efficacy of such a treatment prior to low-temperature test of a notched and welded specimen is also shown in Fig. 7. Not only is the plate strength restored to the yield point, but there is also a plastic extension to fracture equal to that in a simply notched specimen. It is possible to secure at least 1% plastic extension of the whole plate before fracture, even at 50°C below the transition temperature.

Welded wide plates, prepared as above except that saw-cut notches are inserted after welding, invariably show strength and ductility at least equal to those of others which have been stress-relieved in a furnace. Thus, the conclusion may be stated that the low-stress conditions under which brittle failures may occur from slowly applied loading in welded assemblies are due to:

(1) the temperature at which loading takes place being below the transition for the parent material;

(2) the existence of a sufficiently severe notch effect or flaw in association with a welded joint, at least present when the weld is cooling;

(3) the plastic movements which are a result of differential expansions and contractions from the welding operation, which permit the root of any notch effect in the zone heated by welding to sustain sufficient plastic strain to place the material locally in a state of incipient fracture initiation; and

(4) the tensile residual stresses enveloping the notch effect, frequently of yield-point magnitude, which are also an end product of the differential thermal movements arising from welding and which support the early stage of fracture propagation until additional tensile

stresses arising from service loading may sustain it.

These conclusions are not without exception, since complex combinations of events are clearly concerned. Nevertheless, they may be helpful from two points of view; (*a*) by demonstrating that at least four conditions must be satisfied to produce low stress fracture, so that the definite, but not necessarily great, risk of fracture in any steel structure may be assessed; and (*b*) by the examination of methods of improvement of structural conditions under any of the above headings, the risk may be reassessed.

Practical Implications

A study of the hazard of brittle fracture in relation to chemical plant may reasonably be made on the basis of the foregoing four conditions for fracture. In fact, it is possible to discuss, on this basis, the precautions likely to be taken in several classes of construction.

In an extreme case, that of a nuclear reactor vessel, there is almost no experience to be used as a guide to fracture propensity, but all reasonable precautions are likely to be taken in view of the consequences which might follow fracture. Thus, low-transition-temperature materials would be employed to ensure a satisfactory degree of notch ductility at ambient temperature when the reactor is shut-down—bearing in mind any possible impairment as a result of strain ageing or prolonged irradiation. Further, an absence of flaws would be ensured by welding to a stringent, non-destructive testing standard. In addition to this, such a vessel would normally be subject to thermal stress-relief, and residual stress and plastic strain effects would be removed thereby.

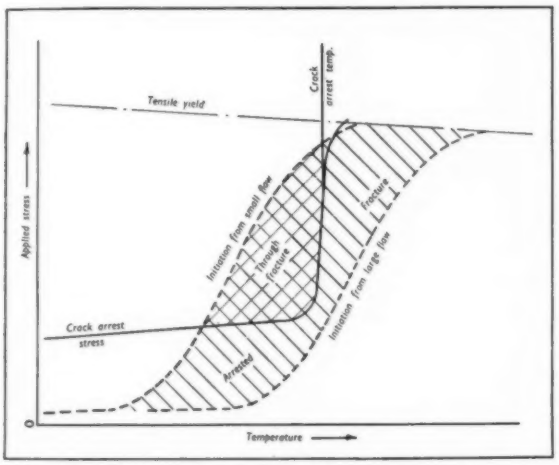

Fig. 6. Brittle fracture strength/temperature relationships for wide plates of the type in Fig. 4 containing longitudinal butt-welds and saw-cut notches.

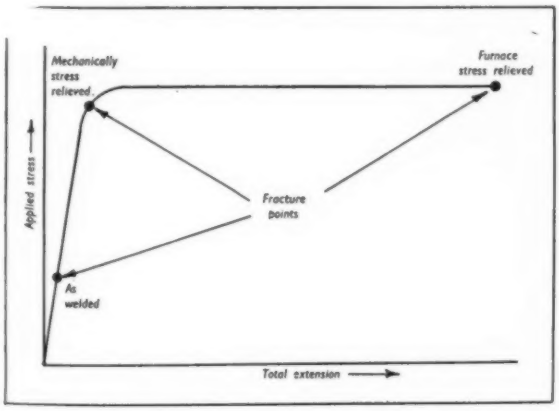

Fig. 7. The influence of various kinds of residual stress relief on brittle fracture strengths and ductilities of welded and notched wide plates.

By contrast, the code requirements for Class 1 type pressure vessels have for many years excluded any specific reference to the notch ductility of parent materials. In spite of this, the use of this class of vessel has been attended by few cases of brittle fracture. Such vessels are not always operated at high temperature, so that it may be concluded that considerable benefit has accrued from attention to the remaining three fracture conditions through use of non-destructive testing and thermal stress-relieving. In some countries even stress-relieving may be omitted for thin vessels.

In spite of the proven efficacy of thermal stress-relieving, it is important to point out that a few casualties have occurred in vessels protected by such treatment without the employment of notch-tough-steels, mainly because of locally severe heating and cooling, when in service after stress-relieving. The limitation arising from such possibilities cannot entirely be ignored.

It has been customary, until recently, to prescribe comparatively fewer precautions against fracture in welded structural work and storage tanks of low-carbon steel. It is also in this category that most fractures have been experienced, even when the comparison excludes differing populations of structure. Thus it is reasonable to conclude that the avoidance of any one of the fracture conditions is likely to give rise to significant reduction of casualties, and the choice may be guided by expediency. From this viewpoint, it is not surprising for site-erected structures, where furnace stress-relieving is uneconomic (except for pipeline components), that the use of steels such as ND 1 with a moderately lowered transition temperature should be attractive. Since fractures have often occurred in the past as a result of quite severe weld flaws, the choice of welding to a partial non-destructive testing standard may also be considered, alone or in combination with moderately improved material. Whereas thermal stress-relieving may be rejected for these large site-erected structures, the mechanical type of stress relief which relies on neutralisation of fracture condition 3 has perhaps not received the attention it deserves. For instance, in certain structures it might be practicable to apply overloads when warm to confer this type of protection. Again, the Linde type of mechanical stress-relieving has been shown to raise brittle fracture strengths in wide-plate tests. In this process, residual stresses along welds are relieved through differential stretching; the latter is produced by thermally expanding wide bands on either side of the weld. A sufficient effect is produced by a differential temperature of 150°C between the weld and the bands, and this is secured with a maximum temperature rise of no more than 200°C in the bands by maintaining a high heat-input rate, fast traverse, followed by a water quench. Practical application of the method has been hindered by the necessity to ensure precise control of temperatures and speeds to produce the optimum reduction of stress. It is not easy to establish, except at the time of application, that sufficient control has been exercised. Nevertheless, the method is worthy of consideration for existing structures.

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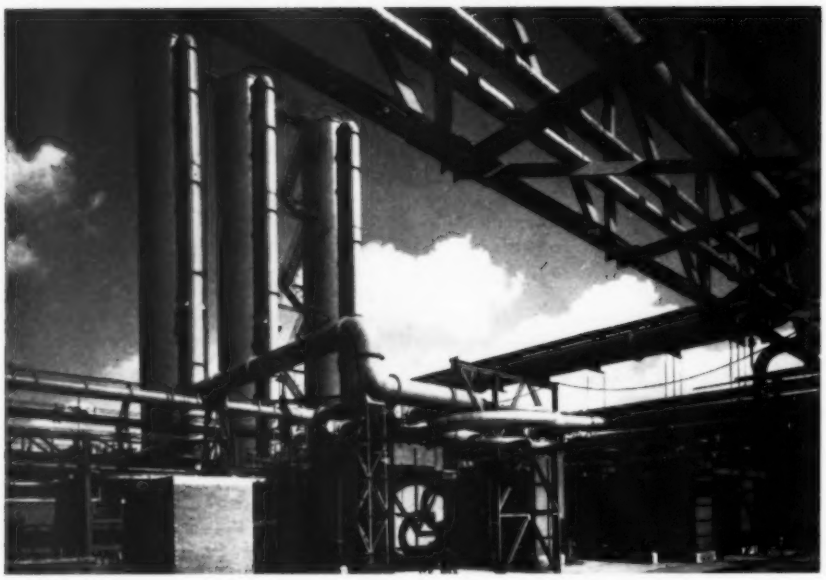


Part of the Avenue carbonisation and chemical plant for the recovery of benzole and naphthalene. (Photo: Woodall-Duckham Construction Co. Ltd.)

THE AROMATIC CHEMICAL INDUSTRY

by S. A. GREGORY

A survey of present and potential sources of aromatic chemicals in Great Britain

FROM the carbonisation of coal are derived a large number of chemical products. The raw materials for these are found principally in the non-aqueous liquid products of carbonisation. Because of their chemical similarity, they are normally grouped together under the heading "aromatics".

The magnitude of this stream of materials is only about 1 part by weight in 30 of the coal originally charged, the main products of carbonisation being, of course, gas and coke. From this stream of liquid products only a few of the components are separated in any condition approaching purity for commercial purposes. In fact, about 1 part in 15 of the liquid products (including pitch) attains use as raw material in the chemical industry. In all, about 0.3% of carbonisation coal achieves aromatic chemical status.

The total amount of coal carbonised each year in Great Britain is about 55 million tons,[1] of which half is consumed by the town gas industry and the other half by the coke ovens. The coke ovens operate at a higher temperature than any of the ovens used in the gas industry, and therefore turn out hydrocarbon mixtures more completely aromatic and tars richer in naphthalene; the gas industry, with lower temperatures, tends to produce more paraffinic material and tars richer in phenols. Technical low-temperature carbonisation yields tars characterised by the presence of polyhydric phenols in quantity. Coke ovens tend to be operated in larger units than gas-works, so that usually the handling of these product streams is more easy to organise and recoveries are better.

Depending upon the coal blend used, so the quantity and composition of the streams vary. In typical coke-oven practice it is taken that every ton of coal carbonised produces 0.01 ton of crude benzole recovered from the gas, 0.01 ton of ammonium sulphate and 0.035 ton of tar.[2] A small amount of benzole is recovered from the tar.

The national production figures suggest that from 55 million tons of coal it is practicable to recover 370,000 tons of benzole in various refined forms (0.0067 ton/ton of coal); 2.35 million tons of tar (0.043 ton/ton of coal).[3]

The majority of benzole recovered comes from the coke ovens. It has been estimated that about one-third of all the crude benzole produced is contaminated with paraffinic material, presumably from lower temperature carbonisation. Coke-oven benzole normally has a composition in the region of 75% benzene; 15% toluene; 7% xylenes; 3% naphtha.[4]

If we assume that all the paraffinic material (low-gravity benzole) goes to motor fuel, there is left potentially some 250,000 tons of benzole readily available for further refining. (It should be noted that there are several processes available for removing paraffinic bodies from contaminated benzoles.) In the above quantity of benzole there is present some 25% of material which may possibly be removed to blend with the motor fuel, leaving not more than perhaps 180,000 tons a year of benzene exclusive of refining losses. The potential toluene is about 37,000 tons a year. The possible xylenes total 18,000 tons and may be less.

The Raw Materials in Tar

The following range of compositions has been suggested for coal tars[5]:

Products boiling up to 200°C	...	4– 8%
between 200 and 250°C	...	15%
between 250 and 300°C	...	9–10%
between 300 and 350°C	...	10–27%
Residual pitch	... ...	62–40%

In such tars coke-oven tar has the highest residual pitch and vertical retort tar the lowest pitch. In the case of coke-oven tar[4] the light oil boiling below 200°C might consist of 0.3% crude benzole; 0.6% cumarone and indene; 1.1% xylenes, cumenes and isomers; 0.7% phenol; 1.3% tar bases. The middle oil might be 1.5% phenol homologues; 0.5% tar bases; 9% naphthalene; 2.5% methylnaphthalenes; 1.5% neutral oils not identified. The heavy oil might contain 3.5% dimethylnaphthalenes; 3% acenaphthene and

fluorene; a small amount of tar bases; 2.5% unidentified neutral oils. The anthracene oil boiling between 300 and 350°C might perhaps contain 4% phenanthrene, 1% anthracene; 2.5 carbazole and allied nitrogen bodies; 5.5% unidentified neutral oils.

Tar and Its Uses

Most of tar distilled is used either for road making or for fuel. A number of the small pre-war tar distilleries were associated with suppliers of road stone. The rise of creosote-pitch mixture as a fuel was accelerated during the recent war and, although its use declined immediately after the war, it is now much favoured as a metallurgical fuel low in sulphur. Nearly two-thirds of the tar distilled goes to these two uses. Much of the pitch made is exported for coal-briquetting.

Not more than 5% of the tar at present distilled is refined to yield chemical raw materials. This includes[3] about 13,000 tons of phenol from a potential yield of 16,000-17,000 tons a year; 37,000 tons of other tar acids from a potential yield of about the same quantity; 43,000 tons of naphthalene from a potential yield of perhaps 80,000-90,000 tons; anthracene (40/50%) 2500 tons from a possible yield of 10-20 times the size.

The Rise of Carbonisation Chemicals

The products of carbonisation have tended to vary in their use over the 200 years in which the coking of coal has been practised. In the earliest days tar was collected for use as a lubricant and as a lamp fuel. From 1819 onwards, tar was distilled to yield naphtha for use as a rubber solvent and also to provide pitch, which was dissolved in naphtha to give black varnish. About the same period ammonia was recovered for use in the manufacture of alum. After 1838 the use of creosote oil for wood impregnation was developed.

The century-old exploitation of benzene as a starting material for dyestuff manufacture was noted in 1956.[7] Up to the beginning of the twentieth century the chemical products of carbonisation (ammonia excepted) usually suggested coal tar colours. This period saw the rise of the by-product recovery coke oven in the manufacture of metallurgical coke. In 1902 some 10% of metallurgical coke was made in this way; in 1906 some 20%; and in 1914 about 60%.

The recovery of benzole from coke-oven gas soon led to the saturation of the needs of the chemical and dyestuffs trades. It was the development of the motor car which showed new outlets for carbonisation chemicals. Tar was distilled to make better road surfaces. Recovered benzole was treated to make a high-grade motor fuel. It was this exploitation of motor benzole which helped to pay for the new coke ovens built in Great Britain after 1930.

The plastics industry began to draw on the products of carbonisation with the development of phenol-formaldehyde resins, a development which showed new fields beyond the supply of phenol for making aspirin and allied antipyretics, and the compounding of disinfectants. In the last decade this demand for the aromatic materials for the manufacture of plastics and the production of new textiles has begun to assume large dimensions, and the petroleum industry has become a supplier, even in Great Britain.

One does not have to seek far for the reason for the entry of the petroleum industry. Coal carbonisation chemicals are essentially increased in supply because of the expansion of the steel industry, which needs metallurgical coke, in the manufacture of which benzole and tar are produced. A great deal of the recent expansion of the town gas industry has been based upon the use of petroleum residues and gases instead of coal. The steel industry is expanding at the rate of about 50% in ten years, but is becoming more efficient in the use of coal. In contrast, the heavy organic chemical industry in Great Britain is expanding at about four times this rate.

Benzene was the first aromatic hydrocarbon to be harnessed as raw material for commercial chemical reactions, a step taken by Perkin. Nowadays some 3 million tons of by-products are made each year from carbonisation, the lion's share of the chemical supply (ammonia excepted) being taken by benzene, of which approximately 150,000 tons are refined each year. Roughly a similar amount of benzene-toluene mixture is converted to motor fuel. Because of the monetary return obtained for the benzole, the majority of the potentially available material is recovered from gas or distilled from tar.

Outlets for Benzene

The estimated principal outlets for benzene in the production of chemicals are as follows:

(1)	Aniline for dyestuffs:	20,000 tons a year
(2)	Anthraquinone group for dyestuffs:	15,000 tons
(3)	Phenol by sulphonation:	25,000 tons (expanding)
(4)	Ethylbenzene for styrene:	25,000 tons (expanding)
(5)	Dodecylbenzene:	15,000 tons
(6)	Monochlorbenzene for D.D.T., etc.	
(7)	Hexachlorbenzene	
(8)	Maleic anhydride	(expanding)

These outlets account for the majority of the refined benzene entering trade. Although the dyestuffs end is relatively well established, items (3), (4), (5) and (8) have been the subject of substantial growth in recent years, and more growth is to be expected. Although the gross production of benzole by carbonisation has only expanded by 25% in ten years, the production of refined material has doubled in that period, at the expense of motor benzole, in order to supply new chemical industries which have come into being during that period.

The suppliers of refined benzole are the large coke-oven plants, the tar distillers, and some specialised benzole refineries. The supplies are limited by the capacity of the carbonisation plants, and it must be remembered that owing to the specification for motor benzole it is necessary to add benzene to the fuel in order to provide a satisfactory distillation range to the material, which otherwise permits the disposal of unwanted toluole and xylole.

Production of aromatic hydrocarbons from petroleum sources is now carried on in at least three plants in Great Britain. In the major units the purpose is to produce high-grade motor fuel, although they are also a potential reserve of low-sulphur benzene to extend the supplies needed in future chemical expansion.

Tar Acids and Phenol

The tar acid group was the earliest of the carbonisation chemical materials to feel the effect of the rise of modern plastics. The need for phenol and cresol to make products of the phenol-formaldehyde type lifted the output requirements beyond those suited to the making of disinfectants and the manufacture of aspirin.

Ten years ago the supplies of natural phenol were insufficient, and a small production of synthetic phenol was necessary to meet requirements. For example, in 1948 the home production of phenol was 13,150 tons, consisting of 10,000 tons of natural phenol and the residue synthetic. There was an import of 6750 tons.

The programme of development for plastics, and even more for the production of nylon, required a substantial increase of synthetic phenol output. Hence, in addition to

the reputed 4500 tons capacity of the Monsanto plant at Ruabon, in 1951 there were built two new plants, one by Monsanto at Ruabon, and one by Synthetic Chemicals Ltd., at Knottingley, just opposite the plant of Yorkshire Tar Distillers Ltd., with a combined capacity of 15,000 tons a pear. Meanwhile, the output of natural phenol had increased at the rate of 50% in ten years. By 1954 the apparent phenol capacity was approximately: natural 12,500 tons; synthetic 20,000 tons.

The estimated principal outlets for phenol in 1954 were:

(1) Phenol-formaldehyde resins, etc. ... 15,000 tons
(2) Nylon, by way of cyclohexanol ... 10,000 tons
(3) Miscellaneous, e.g., aspirin, alkylphenols, diphenylolpropane, cyclohexanol solvents ... ... 7,500 tons

However, the forward programme for the manufacture of nylon suggests that by 1958 there will be a total demand each year of 45,000 tons of phenol. The only possible way of meeting this demand is by further synthetic phenol supply, to the tune of a maximum of 12,500 tons a year. (Natural phenol resources could possibly only supply 3500 tons.) In order to meet this demand, I.C.I. have entered the field of production on a scale of this order of magnitude and currently advertise their product, presumably because their nylon plants are not yet absorbing their full intake.

Phenol Expansion Limited

The possibility of expanding the natural phenol production is strictly limited. The principal activity of producers in recent years has been the reorganisation of refining methods with a view to keeping production costs down.

The natural cresols have not yet had to be supplemented by synthesis. Their principal use is in plastics. Separation of cresol isomers is partly possible by distillation, yielding *o*-cresol suitable for the manufacture of dinitro *o*-cresol, and leaving a *m*-/*p*-cresol mixture suitable for the plastics trade. Tricresyl phosphate is an important plasticiser and and has recently become significant as a petrol additive.

Toluene is present to the extent of about 15% in crude benzole and the estimated potential availability of refined toluene, excluding that from low-gravity toluole (which was actually exploited during the war), is about 50,000 tons a year. In peacetime there is no great demand for nitration-grade toluene, although a fair amount is used in the manufacture of dyestuffs intermediates, perhaps reaching a total of 10,000 tons. Toluene is also a primary material for the manufacture of saccharin and is used to make benzoic acid. The large majority of toluene finds its way into motor fuel, in which it may be blended to comprise up to 50%. It is the toluole contaminated with paraffinic hydrocarbons which is the first candidate for motor fuel.

New Outlet for Toluene

Recently a major new outlet for toluene has appeared. This is in the manufacture of urethane plastics and foams. The quantities involved in Great Britain are not much yet, although, after prior development in Germany, there is currently a large expansion being prepared in the U.S.A. The American output in 1955 was about 500 tons of isocyanates, but there was under construction in 1956 capacity for 15,000-20,000 tons a year, and further capacity of at least 10,000 tons a year is planned.[8]

Of the isocyanates, the principal items are prepared from toluene. In the most common case the toluene is converted to a diamine, which is then treated with phosgene to yield tolyl diisocyanate. On reacting such isocyanates with a suitable polyol in a prepared polyester resin in the presence of water and a catalyst, a foamed plastic is

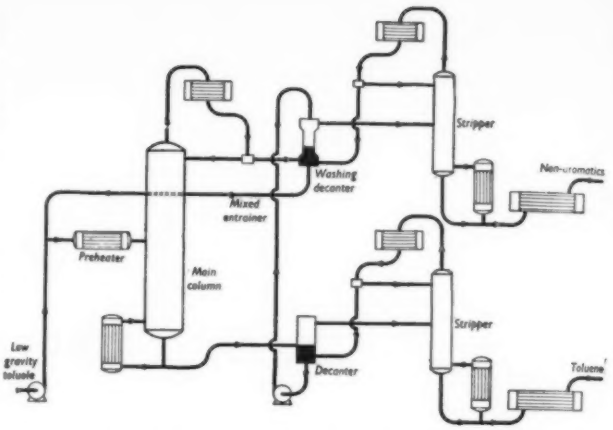


Diagram of plant for the production of toluene from low-gravity crudes, to give yield of nitration-grade toluene in excess of 96%. (Diagram: A.P.V. Co. Ltd.)

produced. Another member of the plastics family which is attracting some interest is polymethylstyrene. The monomer may be made from toluene by a number of alternative routes.

In the immediate future it is reasonable to expect that carbonisation toluene will be able to meet possible demands. Should demand outrun supply, there will be reserves available from the petroleum industry.

The Xylenes

The xylene isomers which constitute xylole were little used as chemical raw materials until the development of Terylene. It is true that some xylole was purified for nitration to use in dyestuffs manufacture, but this only absorbed a small amount of the xylole available from carbonisation sources in Great Britain. Roughly 5% of the crude benzole constitutes xylole, so that the current potential output of xylole is approximately 18,000 tons.

Now, in the manufacture of terephthalic acid for Terylene, the essential hydrocarbon is the isomer *p*-xylene. The normal content of this in the mixture of isomers is about 20%, of which only half may be easily separated.[9] It is therefore not possible to obtain even 2000 tons of *p*-xylene readily from home carbonisation.

The Terylene programme has developed rapidly since 1954, when there was an output of 1000 tons, rising to 5000 tons in 1955 and 10,000 tons in 1956, with a planned output of 20,000 tons a year for the immediate future. The manufacture of 1 ton of Terylene needs more than 0.5 ton of *p*-xylene. Hence the existing output of Terylene, at about 10,000 tons a year, needs at least 5000 tons of *p*-xylene. In order to obtain such a quantity, it was obviously necessary to go outside the carbonisation industry, which under normal conditions would have been able to supply, perhaps, 1000 tons a year.

Adequate supplies have been obtained from Shell's petroleum refineries at Stanlow and Shellhaven, where the "Platformer" units installed to provide aromatic hydrocarbons for motor fuel by catalytic reforming have permitted the separation of a xylole stream by extractive distillation. The *p*-xylene is separated from the mixture of isomers by crystallisation at low temperature, followed by centrifuging. The *p*-isomer has a much higher freezing point than the other two isomers. There is, as yet, no indication that the other isomers are to be exploited in Great Britain for chemical purposes, although the path of development has been pointed by the Oronite Chemical Co., and will be discussed further below.

Naphthalene

Although naphthalene is one of the principal products from coal tar, the chemical industry did not find a use for it until the late nineteenth century. A century ago it was noted that "it is a vexatious circumstance that no important practical use has yet been found for naphthalene", in spite of the fact that "its derivatives are immensely numerous, and, in a theoretical point of view, of the greatest importance . . ."[10] The discovery of the synthesis of indigo in 1882 led to an extensive investigation of the possible and alternative commercial methods for its synthesis. By 1890 the use of phthalic anhydride was discovered. This gave a chemical outlet for naphthalene. The use of phthalic anhydride spread to other sections of chemical synthesis and, today, it is the manufacture of phthalic anhydride which still commands the chief use for naphthalene.

Great Britain's output of naphthalene of all grades is approximately 43,000 tons a year.[3] The output has expanded by 25% in ten years. There has been a change in the proportion refined over this period, and quite recently there has been great emphasis on attaining a specification just adequate for the manufacture of phthalic anhydride, as shown by the installation of new plants. A number of different types of process have been used and include vacuum distillation, crystallisation and washing with methanol, crystallisation and water washing.

The home consumption of naphthalene for the manufacture of phthalic anhydride is currently estimated at about 20,000-25,000 tons a year.[11] A great deal of the remainder is exported to the U.S.A. for use in phthalic anhydride plants. Today the U.S.A. imports some 5000 tons of naphthalene each year to contribute towards its annual output of 150,000 tons of phthalic anhydride. The British export is 8000-9000 tons a year.[12] In the immediate future, however, there is likely to be an increased home demand in order to cope with the phthalic anhydride capacity indicated from the following firms:

Monsanto Chemicals Ltd.: 15,000 tons a year—Ruabon and Newport.

I.C.I. Ltd.: 7500 tons a year—Wilton.

I.C.I. Ltd.: 3000 tons a year—Grangemouth and Huddersfield.

United Coke & Chemicals Ltd.: 4000 tons a year—Orgreave.

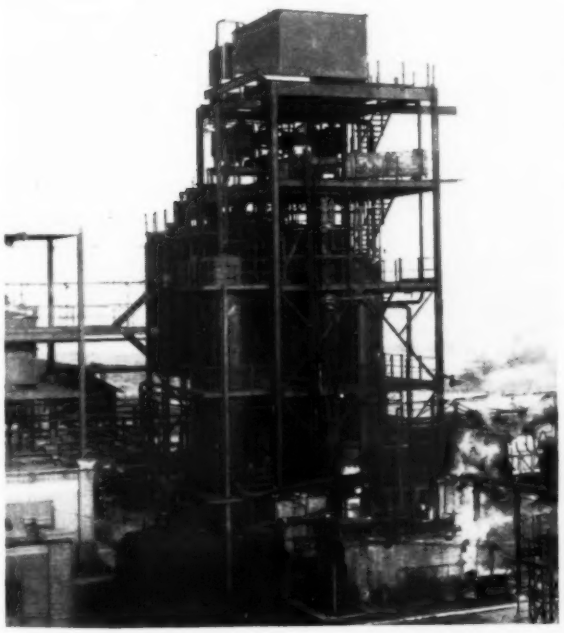
Postans Ltd.: 1000 tons a year—Birmingham.

This suggests a demand for at least 31,000 tons of naphthalene in the near future, with the possibility of further demand from I.C.I. when a rumoured new fixed-bed plant comes into being.

The quantity of naphthalene used for other chemical purposes, such as the manufacture of dyestuffs intermediates and including the naphthols, probably does not exceed 10,000 tons a year. Around 1952 there was a drop in the production of naphthalene intermediates because of the demonstrated carcinogenic properties of the naphthylamines, particularly beta-naphthylamine, but the use of naphthalene has grown again in other dyestuffs channels.

The present increasing demand for naphthalene indicates that either alternative raw materials must be found for the manufacture of phthalic anhydride, or the recovery of naphthalene from tar, and from coke-oven gas, must be improved in the near future.

The Coal Tar Research Association has been exploring the use of residues rich in phenanthrene for the manufacture of phthalic anhydride, and a number of papers have been published on the subject.[13] Outside the use of tar products, there has been a development in the U.S.A. concerning the employment of *o*-xylene. For some years the Oronite Chemical Co. of America has been using *o*-xylene for phthalic anhydride manufacture. More recently there has been an announcement that the Amoco Chemical Corp. will be using a new liquid-phase oxidation process to make phthalic anhydride from *o*-xylene.[14] To make the situation more involved the Oronite Chemical Co. has recently commenced the manufacture of isophthalic acid on a large scale, starting from *m*-xylene. This material is stated to have substantial advantages over the normal phthalic anhydride,[15] e.g., it gives higher melting point resins, is less toxic than phthalic anhydride and has a lower vapour pressure.



Plant for the continuous production of No. 2 benzole and nitration-grade toluene. (Photo: A.P.V. Co. Ltd.)

Other Products

Apart from the major raw materials, there are quite a number of less importance which should not be forgotten.

For example, the tar bases play an important part in some aspects of the fine chemical industry. There is also the carbonisation industry's own resin—cumarone-indene—which is recovered from naphtha fractions, and which is finding much use in the manufacture of floor tiles.

The tar distillers and the benzole refiners are not so aggressive in their new developments as the petroleum industry, but it is encouraging to note that here and there small chemical companies associated with the industry are exploring the market with new chemicals and expanding their research facilities.

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THE SIZING OF ROTARY VACUUM FILTERS: PART 2*

by D. B. PURCHAS, B.Sc., A.M.I.Chem.E.†

Frequently lengthy series of small-scale filtering tests will be made at different form times or different vacua, and, in deciding whether the data available are consistent, allowance must be made for these factors. It is often useful to know also how the output of a filter is likely to be affected by varying the drum speed or submergence (which determine the length of form time) or the operating vacuum. The influence of these factors can generally be predicted from a consideration of the theory of filtration.

Although more rigid, and, therefore, more complex, equations have been developed, the Hagen-Poiseuille Equation is useful for relating the variables

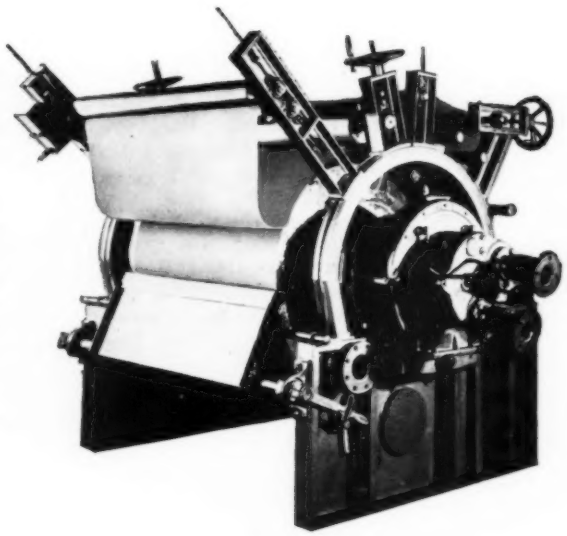
$$\frac{1}{A}\frac{dV}{dt} = \frac{\triangle P}{\mu\left[\frac{\alpha w V}{A} + r\right]} \qquad \ldots\ldots(1)$$

where A = filter area;
V = total volume of filtrate since commencement of filtration;
t = total time since commencement of filtration;
$\triangle P$ = driving force, i.e., pressure drop across the filter;
μ = viscosity of the filtrate;
w = weight of dry cake solids per unit volume of filtrate;
α = specific resistance of the cake solids; and
r = resistance due to the filter medium and piping.

This equation gives the instantaneous filtration rate, expressed as volume of filtrate, at any time, t, after the commencement of filtration through any given element of area. A similar equation expresses filtration rate in terms of weight of dry cake. It may be applied to a continuous rotary filter by integrating V, between the limits o and V_f, with respect to t, between the limits o and t_f, it being assumed that r is negligible (which is frequently true) and that all the other factors are constant:

$$V_f^2/A^2 = \frac{\triangle P/t_f}{\mu\alpha W} \qquad \ldots\ldots(2)$$

In Equation (2), t_f is the cake-forming time, which is equal to the product of the cycle time, t_c, and the effective drum submergence, B; and V_f is the volume of filtrate obtained during the cake-forming time, t_f. It is normally more convenient to express the filtration rate in terms of volume per hour, V_h, which equals $60V_f/t_c$ (assuming t_c is in minutes). From Equation (2),



Rotary vacuum drum filter fitted with one compression roll, wash blanket and spray bars.

$$V_h/A = 60\left[\frac{\triangle P\, B}{\mu\,\alpha\, w t_c}\right]^{\frac{1}{2}} \qquad \ldots\ldots(3)$$

That is to say, the rate of filtration with a rotary vacuum filter is directly proportional to the square root of both the operating vacuum and the effective drum submergence but inversely proportional to the square root of both the cycle time and the form time.

A plot on logarithmic co-ordinates of filtration rate as a function of operating vacuum, at constant submergence and cycle time, should, therefore, give a straight line of slope +0.5; similarly, a plot of filtration rate as a function of cycle time or form time, at constant submergence and operating vacuum, should give a straight line of slope −0.5. In practice, it is usually possible to obtain good straight lines, but the slopes often deviate from the predicted values. The deviation may be due partly to assuming r to be negligible, which is true generally for a new cloth but becomes increasingly less true as the cloth blinds. A further factor is the assumption that α is constant when, in fact, it is a function of pressure for compressible cakes and a function of time when there is migration of fine particles within the cake. However, logarithmic plots of this sort are very useful tools for correlating data obtained under different operating conditions. When carrying out leaf tests, it is convenient to plot the dry weight of cake obtained per test as a function of form time in minutes, at parameters of vacuum, or as a function of vacuum at parameters of form time. A plot of an actual case is shown in Fig. 1. The material handled in this case was a coal slurry.

* Continued from *British Chemical Engineering*, 1957, **2**, 132.
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Having established that a cake weighing G dry grammes, and of a thickness sufficient for good discharge, can be obtained in a form time of t_f minutes, using a filter leaf of A_1 square feet, then the filtration rate, W, expressed in dry pounds of cake per square foot of filter per operating hour can be simply calculated:

$$W = \frac{G \times B \times 60 \times 0.8}{454 \times t_f \times A_1 \times 100} = 0.001057 \frac{G\,B}{t_f\,A_1} \text{ lb/sq. ft/hr} \quad \ldots . (4)$$

It will be observed that a scale factor of 0.8 is included in this equation. The exact value of this scale-factor may vary slightly, depending mainly upon the cake thickness. If the filter leaf is not fitted with a metal skin and a very thick cake is formed, it may be necessary to use a factor as low as 0.6. However, the value 0.8 may be used safely in most cases.

Washing the Cake

It sometimes occurs that the filter cake must be washed to remove residual mother liquor either because the solute is valuable or because the cake is required to be pure. In some instances both considerations apply. The ease with which a filter cake can be washed cannot be predicted and must be established by experiment. In the ideal case, a volume of wash liquor equal to the volume of mother liquor occluded in the cake would remove all traces of the solute. In practice, a single displacement wash generally removes less than 100% of the solute, the exact amount being termed the "washing efficiency". The efficiency is seldom more than 70% and may be as low as 30%. A second wash with the same quantity of wash liquor would be expected to remove a similar percentage of the residual solute, and likewise with a total of n washes. This may be expressed algebraically

$$S = (100-E)^n \quad \ldots . (5)$$

where S is the solute which remains in the cake after washing expressed as a percentage of the solute present in the unwashed cake. The term n, being the number of displacement washes, is defined as the "wash ratio", and is the ratio of the volume of wash liquor used to the volume of mother liquor in the unwashed cake. In practice, a weight ratio is frequently used instead of a volume ratio.

From Equation (5) it will be seen that a semi-log plot of S as a function of n should give a straight line originating in $S = 100$, $n = 0$. In spite of the simplicity of this mathematical treatment, actual experimental data often agree remarkably well with a straight line drawn on this basis. A certain experimental scatter is normally obtained, but any point seriously in error is at once distinguished. If the solute is adsorbed on to the surface of the solid particles in the filter cake, the mechanism of washing is different so that this approach is not applicable. A more rigorous theoretical treatment, allowing for mixing of the wash liquor with mother liquor within the cake, gives an equation of similar form.[5,6] Fig. 2 shows a typical plot, where copper sulphate was being washed out of an ore residue.

Extrapolation of Results

The practical significance of the foregoing discussion is that a means is available by which a limited number of leaf tests may be performed, using a range of wash ratios, giving data which can be extrapolated to other operating conditions. When carrying out washing tests, it is advisable, if possible, to fit the leaf with a metal shim and to use the top-feed technique for the washing operation, spraying or pouring known volumes of wash liquor on to the cake, and observing the time taken for the liquor to disappear from the surface of the cake. This method has the advantage of restricting the short-circuiting of liquor through the edge of the cake and thus gives more reliable data. Where, for example, roller discharge is being used, the leaf cannot be fitted with a shim and the technique is impossible. In such cases the leaf should be held face down in a beaker of wash liquor for a timed period, the quantity of liquor used being established by weighing the beaker before and after the test.

When deciding from these tests what degree of washing can be obtained in practice on a rotary filter, account must be taken of how much time is available for washing during each cycle. Generally the cycle time will have been fixed already by establishing what form time is needed to give a cake of sufficient thickness for convenient discharge. This, combined with the physical characteristics of the type of filter being considered, automatically limits the degree of washing which can be achieved.

The general design of a filter restricts to a definite maximum the portion of the cycle which can be used for washing. In practice, washing is achieved by applying wash liquor to the surface of the cake and allowing the vacuum to suck it through the cake. As the surface of the cake is inclined further from horizontal, however, there is an increasing tendency for the liquor to run or fall off the cake instead of passing through it. On a disc filter, where the entire filtering surface is vertical, this effect is so pronounced that very little useful washing can be achieved. A bottom-fed drum filter allows washing between approximately the 9 o'clock and 12 o'clock positions, corresponding to 25% of the cycle. On a top-fed drum filter, wash liquor cannot be applied until the end of the cake-forming zone, which is at about the 1 o'clock position. Washing is thus limited to about 16% of the

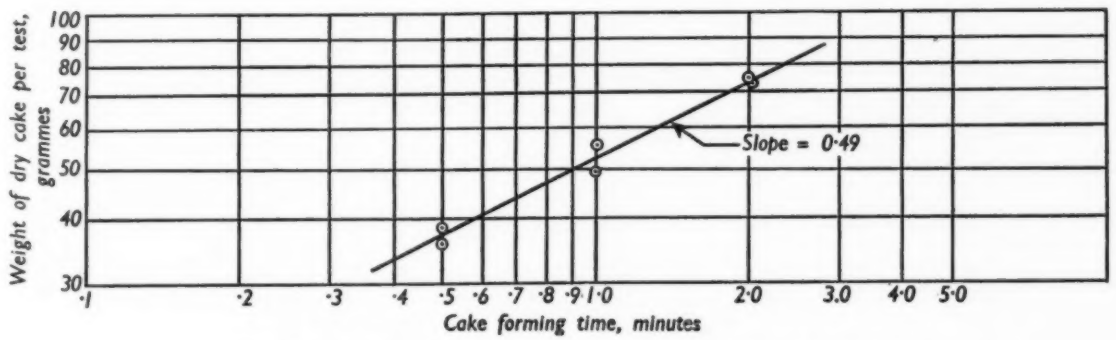

Fig. 1. Graph which refers to the filtration of a slurry containing 17.6% fine coal, having been treated with 1 lb. starch/ton of coal as a flocculent. Filtration rate is expressed as weight of dry cake per test, as a function of form time. The slope is almost the theoretical 0.5.

cycle. The entire surface of a pan filter is horizontal so that gravity assists, rather than hinders, washing; the division of the cycle between the various operations of cake-forming, washing, drying, and discharging is very flexible depending partly on the size of the unit, but often more than 50% can be devoted to washing.

If the washing obtained in the pre-fixed cycle time is insufficient, it is worth considering whether the cake thickness can be reduced, for example, by decreasing the cycle time, the effective drum submergence, or the vacuum. A thinner cake presents less resistance to the flow of wash liquor and therefore allows a greater volume to pass through in a given time. Moreover, the use of the same volume of wash liquor on a thinner cake represents a higher wash ratio and hence gives a purer cake.

Just how great the combined effect of these two factors can be will be appreciated by considering the result of doubling the cake thickness but keeping the wash ratio constant. Ignoring for the moment any difference between the viscosities of the mother liquor and the wash liquor, the rate of flow of wash liquor through the cake is inversely proportional to its thickness; hence, doubling the cake thickness will double the time taken for a given volume of wash liquor to pass through it. But if the wash ratio is to be held constant, the volume of wash liquor used must also be doubled if the cake thickness is doubled. Thus, to double the cake thickness but keep the wash ratio constant, the washing time must be increased by a factor of 4.

In practice, it often happens that the wash liquor and mother liquor are of different viscosities. As a result, the rate of flow of wash liquor through the cake does not become constant until the bulk of the mother liquor has been removed. Thus, doubling the available wash time does not necessarily double the volume of wash liquor used. To avoid error in using the data, it is advisable, therefore, to plot observed wash time as a function of wash volume at parameters of cake thickness. Readings from the curves obtained can then be used in any calculations carried out.

Cake Cracking

At times it will be found that a filter cake cracks almost as soon as it is removed from the slurry. In such a case, washing would clearly be ineffective, since the wash liquor would flow preferentially through the cracks rather than through the solid cake. Cracking does not usually occur during washing, but during the short period when air is being drawn through the cake between the forming and washing zones. If a way can be devised either to restrict this period to a minimum or to delay cracking, it is often possible to overcome this trouble.

On a bottom-fed rotary drum filter, washing cannot commence before the 9 o'clock position, since, below this, the wash liquor tends to fall off rather than pass through the cake. If the drum is kept submerged up to this point, corresponding to 50% apparent submergence, there need be no delay between the cake leaving the slurry and wash liquor being applied. Taken to this extreme, however, there is risk of diluting the slurry in the filter tank with wash liquor; nor will it be so easy to collect the main filtrate and the wash liquor filtrate separately if this is desired. A further disadvantage is that, as pointed out above, a drum filter can only operate at an apparent submergence greater than 40% if it is constructed with trunnion stuffing boxes.

The tendency of a cake to crack generally becomes more pronounced as the cake thickness increases. Reducing the cake thickness can, therefore, sometimes delay cracking long enough for the wash liquor to be applied. Where cracks cannot be avoided, they can sometimes be sealed again by means of a flapper, drag blanket, or compression blanket, these all being attachments which can be fitted to a drum filter. A flapper, which is a device by which the filter cake is slapped at regular intervals, can easily be simulated on a filter leaf by slapping the cake with a spatula. A drag blanket, as its name implies, has one end fixed and the other free to drag across the surface of the drum as it rotates, thus smearing over any cracks. A compression blanket, on the other hand, is formed in an endless loop. It does not drag across the surface of the drum but travels in close contact with it over a considerable distance, pressure being applied by means of two or more compression rolls while the wash liquor is sprayed on top of the blanket.

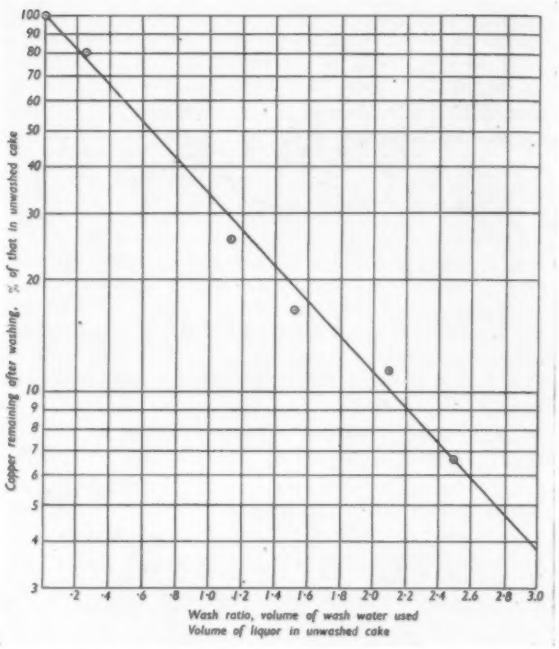

Fig. 2. Washing efficiency as function of wash ratio. Data show the amount of copper sulphate remaining in the ore residue when washing with varying amounts of water.

Occasionally it is not possible by using any of the methods described above to apply sufficient wash liquor to the cake while it is on the filter to reduce the concentration of solubles in the cake to the desired level. In such a case, the use of a multistage filter installation should be considered. This consists of two or more filters in series, the cake discharging from the first being reslurried with fresh liquor before passing to the next filter, and so on. With the cake on each filter being washed, a countercurrent flow of liquor and solids can be arranged. A system of this sort is costly, but it may be justified where a very high recovery of the solubles is required. The necessary investigations with a leaf filter are straightforward but tedious.

Cake Moisture Content

The moisture content of a filter cake is not usually very critical but often it is desired to know approximately what it will be. The foregoing leaf tests will give this information, provided care is taken to select the data referring to the correct cake thickness, drying time, and vacuum. It should be remembered, however, that the drying time is not usually selected independently, but is automatically

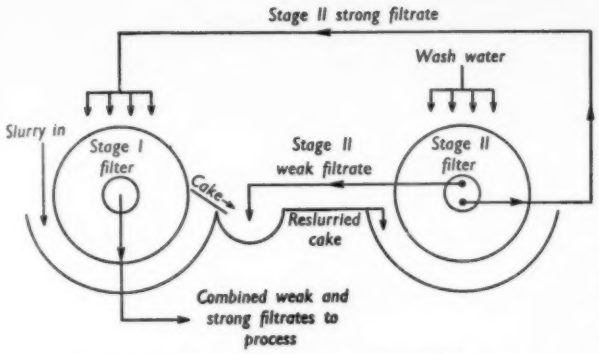

Fig. 3. One possible counter-current washing system with two-stage filtration and intermediate reslurrying. This flow-sheet is designed for a valuable solute where the quantity of wash water used must be restricted to the minimum possible (e.g., extraction of uranium).

fixed by specifying the cycle time and the portions of it which will be devoted to cake forming and washing. Occasionally the moisture content of the cake is critical and it is necessary to reduce it below that obtained in the above tests. There are three basic ways by which this can be achieved:

(i) by the use of mechanical methods to force liquid out of the cake;

(ii) increasing the volume of air which passes through a unit volume of the cake; and

(iii) modifying the physical properties of either the cake or the liquid.

The mechanical methods include flappers, vibrators and compression blankets, which have been described above, and which rely upon the application of mechanical force. Two other methods may also be included in this group, although for differing reasons. A drag blanket, already described, is a mechanical fitting with which cracks in the cake can be smeared over, thus avoiding channelling of the air. With a compressible cake, increasing the vacuum may squeeze out some of the moisture by what is essentially a mechanical means.

Air Volume and Drying

The volume of air passing through a unit volume of cake during the drying period is dependent upon many factors, some of which cannot be varied. Those factors which are generally susceptible to mechanical control are drying time, cake thickness, and the pressure differential across the cake, i.e., vacuum level. To dry the cake further, the volume of air passing through unit volume of the cake can thus be increased by increasing either the drying time or the vacuum, or by decreasing the cake thickness. Unfortunately, the interaction of these factors makes practical control on a rotary filter more difficult. For example, increasing the vacuum will also increase cake thickness unless the form time is reduced, while increasing the drying time, which can be achieved on a bottom-fed drum filter simply by reducing the drum speed, will also increase the cake thickness unless the submergence is decreased. This effect is made worse, since it becomes increasingly difficult to remove further moisture as the cake becomes drier.

The physical properties of the slurry which sometimes can be usefully modified to reduce the moisture content of the filter cake are the viscosity and surface tension of the liquid and the particle size of the solid. A decrease in either the viscosity or the surface tension of the liquid may enable a drier cake to be obtained; greater effect is usually obtained with changes in viscosity.[7] An increase in temperature generally produces a marked decrease in the viscosity of a liquid, and its surface tension can be reduced by the addition of low concentrations of wetting agents. On the other hand, a flocculating agent may cause the particles of the solid to agglomerate, thus producing a cake of more open texture, which not only dries more easily but may also be more freely filtering. The influence of changes in temperature is easily investigated. Unfortunately there is relatively little guidance possible in the use of wetting and flocculating agents and usually they must be tested on a strictly trial-and-error basis. Sometimes it is found that a drier cake can be obtained with one kind of filter medium than with another. The variation from one medium to another is not usually very great, but it may be significant if the moisture content of the cake is very critical.

Filter Selection Important

Where the moisture content of the cake is critical, it should be realised that the type of filter selected may have a major influence. If it is found from the leaf tests that the use of an attachment such as a flapper or compression blanket is needed, there is no alternative but to use a drum filter; these ancillaries cannot be fitted on either disc or pan filters. Moreover, there is a tendency for a disc filter to give a slightly wetter cake than a drum filter when the scraper and air-blow discharge technique is used. This is caused by the construction of the disc, which gives poorer drainage than the drum, and thus increases the risk of filtrate being blown back into the cake during discharge. A slight blow-back of filtrate is fairly common on both drum and disc filters when using this discharge method, so that cake moisture contents predicted from leaf tests may be a little optimistic. There are ways of modifying the construction of these filters to avoid this trouble, but they are not incorporated in the standard units. The use of string discharge, where suitable, also avoids blow-back of filtrate. Finally, the method of constructing a disc filter gives a filtering surface which is less even than that of a drum filter. Consequently, it may be difficult to discharge a cake thinner than about $\frac{1}{4}$ in from a disc filter, even though no trouble is experienced on a drum filter.

Although simple laboratory tests can be employed helpfully to determine the type, size and operating conditions for a rotary filter in handling a given slurry, it must be emphasised that the sample has to be truly representative of the slurry to be handled on a full scale. Ideally, a sample should always be taken directly from the production plant and tested immediately, without submitting it to any changes in conditions, such as temperature, which will not occur on the full-scale filtration plant. Storage even for a few hours is unwise, unless a similar period of storage will occur on the final plant, since many slurries undergo considerable physical change with time, even though none is apparent to the eye, thus drastically affecting their filtration characteristics. In practice, such an ideal sample is seldom available and a sample has to be fabricated. Such sample fabrication is always a potential source of grave error.

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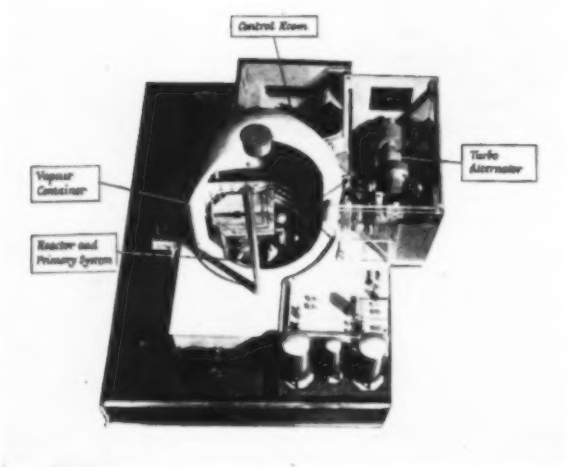
A PACKAGED NUCLEAR POWER PLANT

Details of the first small nuclear power plant soon to be made commercially available in Great Britain are described in this article



Cut-away model of an Alco power plant showing the layout of its principal components

OUTLINE SPECIFICATION OF THE 10-MEGAWATT PACKAGED NUCLEAR POWER PLANT

General

Thermal power generated	46,000 kW
Electrical power generated	10,600 kW
Required for auxiliaries	600 kW
Net electric power available	10,000 kW
Thermal efficiency	22%
Core life before refuel at full power	18 months
Core life at 80% load factor	30 months
Control rod number	7-9
Average fast flux, approx.	5×10^{11}n/cm^{2}sec
Average thermal flux, approx. ...	10^{11}n/cm^{2}sec
Temperature coefficient	About -2×10^{-4}/F

Data for a generating station with condensing turbine and bled steam for feed-water heating

Steam pressure at turbine	375 psig
Steam temperature	439°F
Steam flow from steam generator ...	174,000 lb. per h
Feed-water temperature	280°F
Condenser pressure	2.5 in. Hg
Turbo-alternator output (nett sent out)	10,000 kW

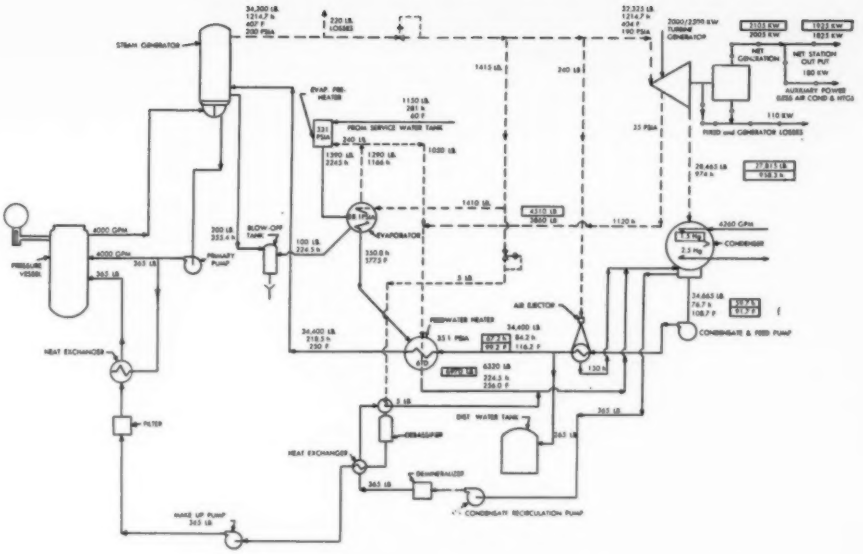
THE Alco pressurised water cooled-and-moderated small nuclear power plant now being made available by Humphreys & Glasgow (see *British Chemical Engineering*, 1957, **2**, 117) in co-operation with Daniel Adamson is the only low-power nuclear plant that has been worked out commercially in small detail. Its special advantages include ease of control and the wide use in it of readily available materials—stainless steel in its construction and demineralised light-water as coolant and moderator.

The plant consists essentially of a primary loop containing the reactor pressure-vessel, the steam-generator, primary coolant, circulating pump and pressuriser; and a secondary system based on a conventional power station. In the 10-megawatt-size of plant the reactor vessel is 16 ft high × 4 ft 6in. in diameter and its working pressure is 1500 psig. The circulation rate of the pressurised water varies with the degree of enrichment of uranium fuel (from 4-12%), but 9000 gallons a minute is said to be typical. The coolant enters the vessel at about 485°F and leaves at about 518°F.

The primary biological shield of the iron, water and concrete type is built round the reactor vessel, and a secondary shield of 3 to 4 ft of concrete surrounds the primary loop equipment. The vapour container also acts as a biological shield and is a domed cylinder about 70 ft high × 70 ft in diameter. Constructed of steel which is welded on the site, it houses all of the high-pressure primary system, and has been designed to contain the products of any possible accident. Adjacent to the vapour container is situated the spent-fuel pit, in which spent fuel elements are transferred to cool off after removal from the core.

The pressuriser of the primary circuit makes use of electrical heaters to maintain the pressure in the hot-water system at a sufficiently high level to prevent steam formation in the reactor, which would cause difficulty in control. All surfaces in contact with the demineralised water coolant and the fuel-element cans are of stainless steel. Uniformity in the amount and purity of the coolant is assured by providing for a fixed rate of bleed and an equivalent make-up through the demineraliser.

In the Army Package Power Reactor (APPR) prototype built for the U.S. Army in Schenectady, New York, the fuel is in the form of 2-ft high vertical flat plates and these are arranged in the core tank in 45 parallel assemblies. The reactor vessel is slightly smaller than the one described above and the biological shield is composed solely of steel cylinders and water, because the components of the reactor have been designed to be transportable by aeroplane. The container of the APPR is surrounded by a concrete shield 5 ft thick.



Heat-balance diagram of a typical Alco nuclear power plant. Figures enclosed thus ▭ *are at 1.5 in. Hg exhaust pressure. Other figures are at 2.5 in. Hg. L.B. is equivalent, in the above diagram, to pounds per hour. Net station heat rate at 2.5 in. Hg is 18,685 Btu/net kWh, and at 1.5 in. Hg, 17,715 Btu/net kWh.*

The radioactive water from the reactor is kept in a closed circuit and does not come into contact with the power-generating side. Since a reactor continues to give off some heat even after it is shut-down, the steam-generator tubes are vertical and the generator unit is mounted above the reactor so that natural convection will keep the reactor from over-heating dangerously should the circulating pumps fail.

Controlling the Reactor

The control of the reactor is effected by the use of neutron-absorbing boron steel rods. They are arranged to drop at 150% of designed power and for other reasons (see below). The action is fast and the control rods start to drop in about 60 milliseconds of the signal being sensed by the actuating mechanism at an acceleration of 24 ft/sec./sec. They are driven by a geared motor through a rack-and-pinion and a magnetic clutch.

A strong negative temperature coefficient contributes to the reactor's inherent safety. If there is a fall in power demand, the turbine takes less steam and the water entering the primary circuit is at a higher temperature. Consequently, its moderating effect is reduced and the heat output of the reactor diminished. Pressure, temperature and water level in the pressuriser, differential temperatures across the reactor, and the primary coolant blow-down and make-up are recorded in the control room. Conductivity is recorded both before and after the water passes through the demineralisers. The reactor shuts-down on receiving signals of the following dangerous conditions: high and low pressure or liquid levels in the pressuriser; high reactor outlet temperature; high steam generator outlet pressure or temperature; low primary coolant flow; and short reactor period. The reactor may also be shut-down manually.

Operational monitoring is provided at important points to indicate immediately any abnormal conditions which might be hazardous to staff, either within or beyond the control areas. All instruments actuate visual or audible alarms on the main control panel.

Normally, the fuel has to be changed once every one or two years, depending upon the load factor. Renewal of the fuel requires the reactor to be shut-down. Operators then enter the vapour container, unbolt the reactor cover plate with long-handled tools through a depth of 9 ft of water, lift the radioactive fuel assemblies several feet and pass them through a transfer tube leading to the storage pit outside the vapour container. The new fuel assemblies are not radioactive and can therefore be lowered directly into position from above.

The manufacturers state that all the major components have been tested thoroughly, and they have every confidence that the plants will function with the minimum of teething troubles. No corrosion difficulties have arisen in the use of hot, pure water under pressure. An outline specification of the 10-megawatt plant is given in the accompanying tables.

Master Slave Manipulator

NEW REMOTE-HANDLING equipment designed and developed at the request of AERE, Harwell, is being manufactured by Savage & Parsons. Each manipulator, or "mechanical hand", comprises over 500 counter-balanced moving parts, and is made mainly of alloys and stainless steel for lightness. The manipulators, it is claimed, can reproduce all movements of a human hand, and make possible the remote control of complex and delicate experiments and operations on radioactive and toxic materials through protective walls and screens several feet thick. Most of the atomic energy establishments in Great Britain will be supplied with this type of manipulator during 1957, and several Commonwealth and continental countries are also showing interest in the equipment. The manipulator was designed to a Harwell specification by a team at the Watford factory of Savage & Parsons, the elaboration of which took six months. The manufacturers state that further development work is in hand to produce servo-assisted manipulators that will operate over distances of half-a-mile.

The manipulators can be used in conjunction with three-dimensional television equipment such as that developed by Marconi for AERE; in fact, Marconi and Savage & Parsons have made an agreement to co-operate in the supply of 3-D television apparatus and manipulators to atomic energy establishments throughout the world. The television equipment gives the operator a detailed 3-D close-up picture of the experiment on a 14-in. screen, and the image is intended to supplement the view obtained directly by observation through the window of the operating chamber. The Marconi equipment consists of a double camera, double control and monitoring equipment.

PART 2

PORTABLE APPARATUS FOR DETECTING FLAMMABLE GASES AND VAPOURS

by E. H. COLEMAN

The modern counterparts of the Davy lamp are used for detecting methane and the deficiency of oxygen in mines, and for this purpose are probably the most widely used of any of the flammable gas detectors. In the presence of a flammable vapour, the shape, size and colour of an oil flame on a wick undergo changes which can be interpreted by the operator who needs only a short simple training. The limits of sensitivity to methane are usually considered to be between 1.25 and 4.5% of methane, i.e., 23 to 85% of the lower flammable-limit. The lamp has the advantage that, not only does it indicate the presence of methane, but it indicates by diminution of the flame when the oxygen content of the atmosphere is low.

Flammable gases are detected most easily with flames of low luminosity and, when used for methane detection, the wick of the lamp is adjusted to produce a small, almost non-luminous flame. A considerable amount of work has been carried out on the production of non-luminous flames for flammable gas detectors. Redwood[28] experimented with an alcohol flame, and Clowes and Ashworth[29] used a hydrogen flame for miners' lamps. In the Clowes-Redwood lamp[30] petroleum-vapour concentration was determined from the size of a hydrogen flame. Recently, Woodhead[31] has suggested using non-luminous flames of paraldehyde or aerated butane.

The Spiralarm lamp is an alarm-type detector. A special petroleum spirit is burnt with a luminous flame on a wick in a safety lamp and the flame heats a bimetallic spiral. In the presence of a flammable vapour the flame increases in size, so that the spiral opens farther to operate the contacts of an electrical alarm (see Fig. 5). In addition to its use in coal mines, for which it is an approved instrument, it has been used widely for giving warning of dangerous concentrations of flammable gas in sewers. Flame safety lamps require adequate ventilation to supply air to the flame, but are made flameproof by gauze screens surrounding the flame. These screens are adequate protection in methane, but tests would be necessary to assess their efficacy in other gases.

If the concentration of flammable gas is above the upper flammable-limit, or if the atmosphere is deficient in oxygen, the mixture either may not burn or the combustion may be incomplete. In such circumstances, instruments using combustion for their operation might not indicate the presence of dangerous concentrations.

Poole[8] has shown that mixtures containing more than twice the lower flammable-limit of vapour produce no further increase of filament temperature, and Philip and Steele[13] noted that errors can arise because the filaments may continue to glow in rich mixtures after the heating current has been switched off. The limitation is recognised by the manufacturers of combustion instruments, who recommend that a diluting device be attached when rich mixtures are expected. This is essentially a standard-sized orifice in the inlet tube so that a proportion of air is drawn in with the test sample and the mixture is below the lower limit. It is thus necessary to use a correction factor. The diluting valve should be in a position where air can be drawn in, but this may not always be possible. Catalytic combustion meters working with catalysts such as Hopcalite would probably be less affected, since the oxygen is supplied, at least in part, by the contact bed.

Explosimeters are most often used to indicate when the flammable gases approach a hazardous concentration—while the mixture is still below the lower limit. Normally the hazards to be guarded against are not due to rich mixtures. If instruments are required to operate in rich mixtures, the use of those not dependent upon combustion would be advantageous.

Thermal Conductivity Instruments

In discussing instruments which measure the rise of temperature of a filament (*British Chemical Engineering*, 1956, **2**, p. 143), it was pointed out that the gases also cool the filament. This cooling is due to the thermal conductivity of the gas, to convection and to radiation. The cooling effects have been used extensively for measuring gas concentrations, and the use of thermal conductivity has been discussed by Daynes[6] and Brown and Dean.[7] In these instruments, the temperature of a heated filament exposed to the gas is compared with that of a comparison filament exposed to a reference gas, usually air. The temperature difference can be positive or negative according to whether the gas has a lower or higher conductivity than the reference gas. Hydrogen and methane are the only gases among those

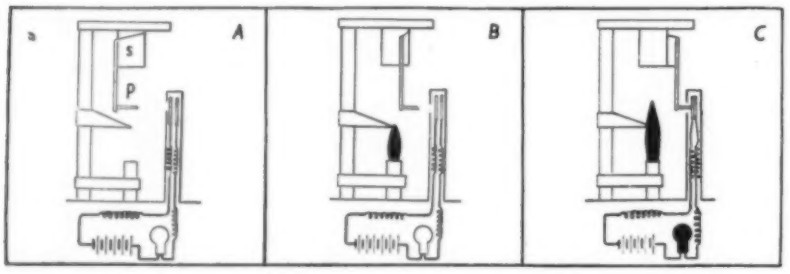


Fig. 5. Diagram showing method of operation of the Spiralarm. s, *the spiral;* p, *the pin;* A, *cold;* B, *normal flame;* C, *alarm position. The flame causes the spiral to move the pin to close the electric-lamp contacts.* (*Diagram: J. H. Naylor Ltd.*)

listed in Table 2 which have a conductivity higher than that of air.

The first use of thermal conductivity for gas analysis was by Somzee[32] and Koepsel,[33] but the major development is due to the work of Shakespear,[34] who designed a satisfactory instrument for detecting hydrogen leaks. As with the heated-filament type of combustion instrument, the change of temperature is measured by making the sensing and compensating filaments the opposing arms of a Wheatstone bridge. Although the filaments operate at lower temperatures than in the combustion instrument, they are still liable to attack by gases to which they are exposed. Englehardt, of the United States, protected the filaments by embedding them in a quartz sheath and this practice is now widely adopted. The operating temperatures are between 180 and 300°C, as, in this range, the differences of thermal conductivity are most easily discerned. Above 300°C, catalytic combustion may occur on exposed filaments and effects due to radiation and convection become more important.

It will be seen from Table 2 that hydrogen is easily determined by conductivity measurement, and that the detection of gases with a conductivity similar to that of air would be difficult. The values of the thermal conductivity of many solvent vapours suggest that this type of instrument might be used successfully for measuring the vapours.

Thermal conductivity instruments are designed to emphasise the heat loss due to thermal conductivity and to reduce heat losses due to radiation and convection, the latter being related to the density and viscosity of the gas. To provide an instrument suitable for gas measurement in methane drainage from mines, Pritchard[35] modified the cell and filament dimensions, and the filament temperatures, so that convection and radiation were important contributors to the heat losses. The modified instrument thus uses a combination of properties and it is possible to measure the concentration of methane over a wide range, in the presence of carbon dioxide, carbon monoxide and hydrogen. A disadvantage of the thermal loss instruments, which is shared by many other instruments relying on physical properties, is that they respond similarly to all gases having similar physical characteristics, irrespective of their combustibility.

Several instruments use the refractive index of a gas to measure its concentration. The instruments are based on the Jamin or the Rayleigh interferometers in which differences of refractive index between the gas and a reference gas, usually air, are made to produce interference fringes, the movement of which can be measured. The Rayleigh instrument has been developed by Zeiss & Co.[2, 36] as a mines methanometer and flammable gas detector. The early instrument was bulky and weighed 13 lb., but later developments have reduced the dimensions. The instrument measured 0 to 10% methane and was sensitive to 0.1%. Two per cent of benzene gave a full-scale deflection and 0.1% could be detected.

Several Japanese instruments have been produced, all based on the Jamin interferometer. In the original instrument by Doi,[37, 38] the fringes were adjusted to a fiducial mark by varying the gas pressure, and the concentration of vapour was determined from a manometer reading. The instrument measured down to 0.01% of petrol vapour. Later instruments for methane measurement were designed by the Riken, Toka and Shinko companies, in which the fringes are adjusted by rotation of the compensator prisms. These instruments weigh from 1 lb. 12 oz. to 3 lb., and are compact. Tests on them have been made by the Safety in Mines Research Establishment[39] and Maas.[40] The instruments cover the range 0 to 6% of methane and will detect 0.1%. Analyses can be made in about 20 seconds. The Riken instrument is approved for use in United States Mines.[11]

The refractive index of carbon dioxide is close to that of methane, and it is therefore necessary to remove carbon dioxide by using absorption tubes, which also contain a water-vapour absorbent. By making successive measurements with and without the carbon-dioxide absorber, it is

TABLE 2.—PROPERTIES OF GASES AND VAPOURS

Compound	Mol. wt.	Boiling point °C	Vapour density S.T.P. g/l	Viscosity Temp. °C	Viscosity Micro poise	Coefficient of diffusion into air Temp. °C	Coefficient of diffusion into air cm^2/s (Air/Air = 1)	Specific inductive capacity Temp. °C	Specific inductive capacity Dielectric constant $\epsilon = 1 + \Delta \times 10^{-6}$ ϵ (vacuum) = 1 Δ at 1 atm.	Relative magnetic susceptibility Oxygen = 100	Velocity of sound at 0°C m/s	Refractive index (D line) $1 + (n \times 10^{-6})$ n	Relative thermal conductivity Air = 1 at 0°C	Relative thermal conductivity Air = 1 at 100°C	Heat of combustion k cal/mol	Lower flammable limit per cent by volume	Heat from combustion of 1 l. of lower flammable limit mixture k cal
Air	—	—	1.293	18	183	—	1	0	0.59	—	332	290	1	1	—	—	—
Carbon dioxide	44	−7.85	1.977	19	150	0	0.139	0	0.98	−0.63	258	450	0.62	0.72	—	—	—
Water	18	sublimes 100	0.803	0 / 100	88 / 127	0	0.220	140	7.9	—	401	250	—	0.76	—	—	—
Oxygen	32	−183.0	1.429	23	204	0	0.178	0	0.52	100	317	275	1.09	1.05	—	—	—
Nitrogen	28	−195.8	1.251	23	176	—	—	0	0.60	—	338	300	1.04	1.01	—	—	—
Acetone	58	56.5	2.55	100	93	—	—	20	25.9	—	208(58°)	1090	0.41	0.55	427	3.0	0.58
Acetylene	26	−88.5	1.7	—	—	—	—	0	1.34	−0.37	327	610	0.78	0.90	312	2.5	0.35
Amyl acetate	130	148	5.82	—	—	—	—	—	—	—	—	—	—	—	1043	1.1	0.52
Benzene	78	80.1	3.48	13	15.1	0	0.077	100	2.8	—	193(15°)	176	0.37	0.37	782	1.4	0.49
Carbon disulphide	76	46.3	3.39	14	96	20	0.089	0	2.90	−0.51	189	1480	0.29	0.23	247	1.25	0.14
Carbon monoxide	28	−190	1.25	15	172	10	0.102	0	0.69	−0.35	337	330	0.96	0.96	68	12.5	0.30
Ethane	30	−88.3	1.375	0	84	—	—	0	1.50	—	303	—	0.81	—	368	3.3	0.54
Ethyl alcohol	46	78.5	2.06	100	108	40	0.102	100	6.5	—	231	880	—	0.88	328	4.3	0.63
Ethylene	28	−103.9	1.245	15	99	—	—	0	1.44	−1.33	314	—	0.74	0.97	332	3.0	0.45
Di-ethyl ether	74	34.6	3.31	0	68	0	0.078	100	4.9	—	179	1530	0.55	0.72	652	1.9	0.55
Hexane (n)	86	69	3.85	—	—	—	—	—	—	—	184(80°)	—	0.46	—	990	1.25	0.55
Hydrogen	2	−252.8	0.09	21	88	—	0.634	0	0.26	−0.12	1270	140	7.15	6.8	68	4.0	0.12
Methane	16	−161.5	0.72	20	108	—	—	0	0.94	−1.18	432	445	1.32	1.72	211	5.3	0.50
Octane (n)	114	125.8	5.09	100	68	0	0.051	—	—	—	—	—	—	—	1303	1.1	0.64
Pentane (n)	72	35	3.21	25	68	—	—	100	2.5	—	191(43°)	171	0.52	0.70	833	1.5	0.56
Propane	44	−42.2	2.01	—	—	—	—	—	—	1.33	—	—	0.62	0.83	526	2.2	0.52

possible to measure both of these gases. An oxygen deficiency produces an apparent increase of methane concentration, and air at 100% humidity at 20°C will give a false reading of −0.63% of methane. From Table 2 it appears that the instruments would be suitable for the detection of acetone, ether and alcohol, all of which have refractive indices very much greater than that of air.

Diffusion, Viscosity, Adsorption, Density

The differences between the physical properties of the vapour and of air can be used to produce pressure changes which can be interpreted in terms of concentration. The properties which have been used in this way are rate of diffusion, adsorption by charcoal, viscosity and density.

The difference between the rates of diffusion of vapours and of air has been used in many instruments, the first use being by Ansell[2] to measure methane concentrations in coalmines. Later instruments are the Vulkan-Severin[2] and the Gluckauf.[41] The instruments contain two chambers separated by a permeable membrane. One chamber contains air and the test sample is drawn into the other. Differential diffusion through the membrane causes a pressure difference between the two chambers. In the Vulkan apparatus this is observed on a sensitive manometer. Scale readings for air containing 1% of vapour were:

Hydrogen	+10.7 mm.
Illuminating gas	+ 6.0 mm.
Methane	+ 1.9 mm.
Carbon dioxide	− 1.3 mm.

Since carbon dioxide reduces the indications due to the flammable gas, it must be removed with absorption tubes.

The Gluckauf is an alarm-type instrument. The change of pressure deflects a flexible membrane which operates an electric contact in an alarm circuit. An adjustment is provided to preset the instrument to operate at any given concentration. The instrument is 27 cm. long and weighs 400 g. and can be lowered on a cord into tanks, etc. The vapour detector made by the National Fire Protection Co. Ltd.[42] is an alarm-type instrument for use in fixed installations. The vapour is adsorbed by activated charcoal and the pressure difference between the air inside the adsorption vessel and the ambient atmosphere is made to operate the electrical contacts of an alarm.

Two instruments, the Fagelston[43] and the Union Apparate,[44] operate by the comparison of the viscosity of vapour-air mixtures with that of air. Air and the test sample are drawn by a small pump through orifice plates or capillary tubes into two compartments, and the vapour concentration is indicated by a manometer showing the difference of pressure between the compartments calibrated in terms of gas concentration. Manometer readings of the Fagelston instrument for 1% of vapour were:

Methane in air	5 mm.
Hydrogen in carbon dioxide ...	15 mm.
Hydrogen in oxygen	13 mm.
Carbon dioxide in air	15 mm.
Carbon dioxide in carbon monoxide	15 mm.
Coal gas in air	5 mm.

For 1% concentrations in air the Union Apparate gave pressure differences of:

Petrol	22.5 mm.
Benzene	19.0 mm.
Ether	20.5 mm.
Carbon disulphide	16.0 mm.

It is claimed that this instrument will measure concentrations as low as 0.02%. By using an aneroid gauge instead of a manometer, the apparatus was developed into a continuously-recording instrument.

The Ranarex apparatus by Allgemeine Elektrische Gesellschaft of Germany measures the differences between densities of air and solvent vapours. The apparatus is bulky and heavy and is not suited for measuring small concentrations below 10 g./m.^{3} (0.3% by volume of benzene). All these instruments use air as a reference and require purging with air between successive readings. This could be difficult if they were used in mines or compartments where pure air is not accessible.

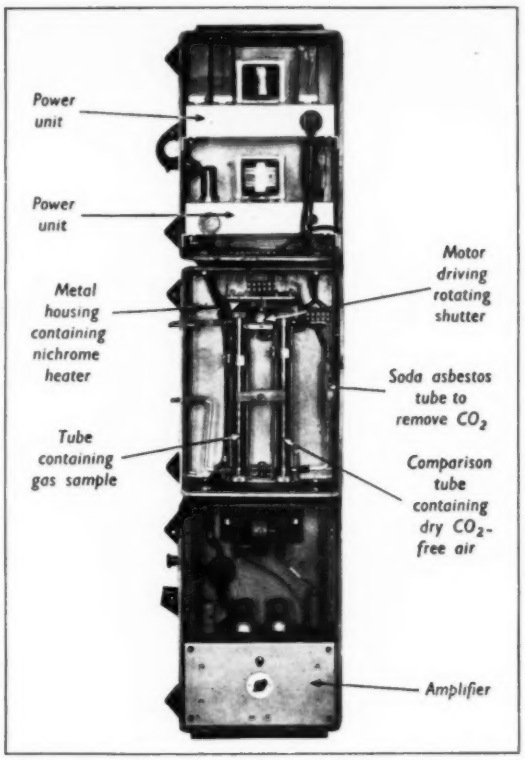


Fig. 6. Interior of an instrument employing the absorption of infra-red radiation. (Photo: Sir Howard Grubb Parsons.)

Other Instruments

Ionisation by α-particles from a radioactive material has been used in a fire detector developed by the Pyrene C-O-Two. Co. of the United States.[45] A similar device[46] has been used for measuring ethylene, hydrogen, ethane, carbon dioxide and nitrogen. The test sample is drawn between two electrodes and the space between is bombarded by the α-particles. The presence of solvent vapours affects the current flowing and this change is indicated, after electronic amplification, by a meter. The sensitivity is 0.2 to 0.3 moles % in binary mixtures.

The dielectric constant of gases has been used to measure the concentration of methyl bromide discharged for fire protection into aircraft engine nacelles.[47] The instrument was adapted from a standard airborne type 5 radio altimeter, a small and compact instrument which measures height by the changes of capacity of a small condenser. Changes of 6 ppm in dielectric constant could be determined. The dielectric constant of methyl bromide is 1.0068 at 100°C (air 0°C = 1.0006) and, in an instrument giving a full-scale deflection with 12.5% methyl bromide, it was possible to measure a change of concentration of 0.06%. From the data of Table 2, the instrument would not be expected to measure differences of less than about 2.0% methane, but would be very much more sensi-

tive to alcohol, acetone or ether. Carbon dioxide and water vapour would require removal.

The velocity of sound in gases varies with the density, and D. W. Forbes[12, 28] developed a mines-gas detector in which the methane concentration was measured from the change in velocity of sound. Early instruments used sonic frequencies which required the use of long resonance-tubes, but the development of methods of producing supersonic frequencies has permitted considerable reduction in the dimensions of the apparatus, although, as yet, no truly portable instrument has been developed.

The absorption of a particular band of radiation is characteristic of a given material, and the absorption in the ultra-violet and more particularly in the infra-red ranges of 1 to 15μ has been used to measure the gas concentration. The application of infra-red methods to gas analysis was developed originally in Germany by K. Luft[18] and E. Lehrer, but instruments such as those by Sir Howard Grubb Parsons & Co. Ltd. and Infra-red Development Ltd. (see Figs. 6 and 7) are now marketed in this country. In these instruments, a split beam of infra-red radiation traverses a cell containing the sample and a reference cell containing air, and then enters a two-compartment condenser cell containing the gas to be determined. The sample behaves as a radiation filter and, therefore, one compartment of the condenser cell receives more radiation of the wavelength absorbed by the gas than the other and becomes warmer, causing an increase of pressure. The pressure difference thus set up deflects a sensitive membrane and causes capacity changes which are amplified electronically and measured. In a modification by Siemens and Halske, the temperature difference is measured by thermocouples. The apparatus is bulky and expensive and also requires skilled maintenance. It can be used for monitoring processess such as solvent recovery, and its readings are specific for the gas being investigated. It is, of course, only suited to gases having a characteristic absorption of infra-red radiation, but this is a property of vapours of the solvents usually encountered.

The magnetic properties of oxygen and nitric oxide have been used for the continuous measurement of these, the only paramagnetic gases. If a heated wire is placed in a non-homogeneous magnetic field, and surrounded by a paramagnetic gas, the wire is cooled, not only by radiation, conduction and convection, but also by additional gas currents caused by the magnetic field. The principles have been described by Klauer[49] and Medlock[50] and commercial instruments have been produced by G. Kent Ltd. of Great Britain (see Fig. 8), and the Hays Corporation of the United States. The principal application is for the measurement of oxygen, which can be determined to within 0.05%.

An alarm-type instrument has been described by White.[51] A cartridge of alumina is impregnated with an alkali metal salt and heated to 300°C. In the presence of a flammable gas, the cartridge becomes electrically conductive and, if it is part of an electric circuit, the current which then flows operates an alarm. It does not give a quantitative response, but is claimed to detect a few parts of hydrogen per 10,000 of air and is more sensitive to heavier combustible gases. It requires a heater voltage of 10-15 V and a d.c. voltage of about 300.

The Page pocket-size apparatus has been advertised by The Davis Emergency Equipment Co. of the United States.[52] The instrument is the size of a fountain pen, weighs 3 oz. and has a red light which flashes in air but becomes steady in flammable atmospheres. The principle of operation has not been stated.

Many gases react chemically to produce visual effects such as coloration or darkening of test papers or pumice granules impregnated with suitable reagents. With instruments based on this principle, a measured volume of the atmosphere is drawn by a small hand pump or bellows through a tube containing impregnated granules or filter paper. The concentration is determined by comparing the size or colour of the stain produced with printed standards.

A series of test methods has been described in a D.S.I.R. leaflet,[53] and among them are tests for carbon monoxide, benzene and carbon disulphide. The Mine Safety Appliances Co. (Fig. 9) and Dräger of Germany produce a series of indicator tubes for different gases. The ranges covered are 30 to 3000 ppm for aromatic hydrocarbons, 10 to 5000 ppm for carbon monoxide, 500 to 13,500 ppm for hydrocarbons and 13 to 3000 ppm for carbon disulphide. These tests are usually very sensitive to low concentrations, and thus find wider application for use in testing atmospheres for toxicity than for flammability hazards.

Discussion

In deciding which of the many available instruments is most suitable for a particular purpose, the advantages and disadvantages of any given type must be weighed carefully. An explosimeter should satisfy certain minimum demands:

(1) Since it may be used in atmospheres which may be flammable, it must not propagate flame or ignite

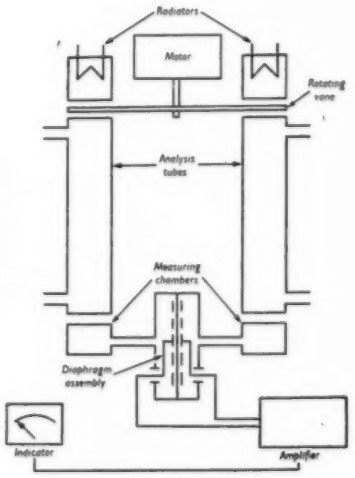


Fig. 7. Diagram showing the principle of gas detection by the absorption of infra-red radiation. (Diagram: Infra-red Development Ltd.)

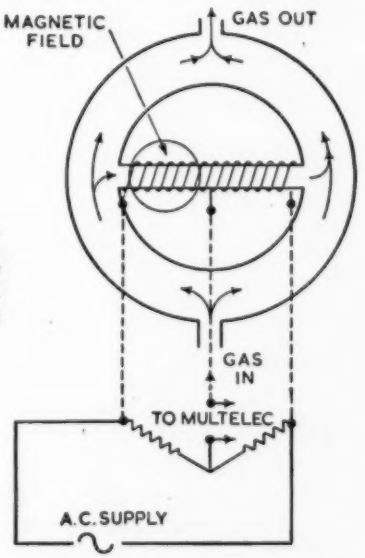


Fig. 8 Diagram showing how the paramagnetic property of gases is used. (Diagram: George Kent Ltd.)

vapours outside the instrument.

(2) The instrument should retain its reliability over a long period and not require frequent recalibration.

(3) Any latitude in calibration or indication should not cause the instrument to indicate less than the actual concentration.

(4) It should be easy to check the calibration.

In addition to these essential requirements, there are other features which are desirable:

(a) The indications should be obtained rapidly to permit the operator to sample a compartment at a number of points.

(b) The instrument should not require highly skilled operators, and its indications should be direct and easily understood without the use of correction factors or auxiliary scales.

(c) The instruction manual should be worded simply, and should draw attention to unsuitable practices and applications—e.g., some instruments designed for use in hydrocarbons are not suitable for use with leaded petrol.

(d) It should be easy to replace broken or worn components and maintenance by skilled mechanics should not be necessary.

(e) The apparatus should preferably be compact and portable so that it can be taken into restricted spaces. It must be robust enough to withstand a reasonable amount of rough use, and should not endanger the operator if broken.

Although there are statutory requirements for the accuracy and reliability of gas detectors intended for use in coalmines, there are no existing standards of performance of explosimeters for general and industrial use, and the only official tests made are those to ensure that they do not propagate flame to the atmosphere outside the instruments when used in a flammable atmosphere.

The commonest mines-gas detectors are the flame safety lamps and before approval they are required to pass a series of tests designed to assess accuracy and robustness.[54] It is required that flame safety lamps shall be sensitive to 1% of methane. Where the Coal Mines (Ventilation) Act of 1947 is applicable, the use of methanometers of greater sensitivity and precision is required. Over a range of 0 to 1.5% methane (0 to 28% lower limit), the readings must be within ±0.05% of the true value.

The United States Bureau of Mines has published specifications for methane detectors intended for use in coalmines.[11, 55] Instruments are separated into two classes:

(1) Detectors with which the user is able to detect as low as 1% and as high as 3% of methane.

(2) Indicators which must give indications as low as 0.25% and up to 4% methane. For instruments in this class minimum and maximum readings for given concentrations are specified. These are given in Table 3.

TABLE 3. ALLOWABLE VARIATION IN SCALE READINGS OF METHANE INDICATORS*

CONCENTRATION OF METHANE IN MIXTURE		MINIMUM READING		MAXIMUM READING	
Per cent. by volume	Per cent. of lower flammable limit	Per cent. by volume	Per cent. of lower flammable limit	Per cent. by volume	Per cent. of lower flammable limit
0.25	4.7	0.10	1.9	0.40	7.5
0.50	9.5	0.35	6.5	0.65	12
1.0	19	0.80	15	1.20	23
2.0	38	1.80	34	2.20	41.5
3.0	57	2.70	51	3.30	62
4.0	75.5	3.70	70	4.30	81

*United States Bureau of Mines Schedule 8C

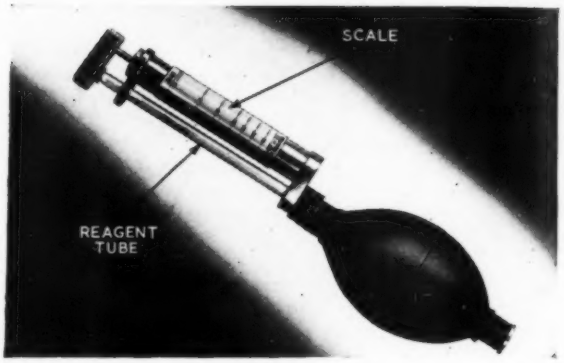


Fig. 9. A pocket chemical-indicator for detecting gases (Photo: Mine Safety Appliances Co.)

It will be noticed that greater discrepancies are permitted by the American than by the British regulations. In the list of suggested requirements in this paper, it is considered that any error should be positive, whereas variations permitted by the American regulations are equally positive and negative. It is understood that one commercial firm calibrates explosimeters for use with hydrocarbon vapours to read not less than the actual concentration, and not more than 15% above; i.e., at 75% of the lower flammable limit the instrument should indicate between 75 and 90%.

Safety Limits

The vapour concentration indicated by an explosimeter is that at the sampling point, and in order to allow for the possibility of the existence of pockets of higher concentrations and to provide a sufficient warning of the building up of gas concentrations, it is necesary to allow a margin between what may be termed the "hazardous limit" and the "flammable limit". It is not possible to suggest a specific figure for this margin, since it will vary so much with circumstances.

In connexion with the differentiation between "hazardous" and "flammable limits", the Coal Mines Act 1911[56] states that 1.25% methane (23% of the lower limit) is considered dangerous where naked lights are used or 2.5% (46% of the lower limit) where safety lamps are used. The safety margin is especially important with alarm-type explosimeters. They give no warning until a predetermined vapour concentration has been attained, and thus the process of any gradual building up of concentration cannot be followed. In some conditions, the actuating concentration of such instruments should therefore be lower than the "hazardous limit" fixed for continuously indicating or recording instruments.

The principal advantages and disadvantages of the widely used types are summarised below. The instruments can be grouped under two main headings, (a) those using combustion for measurement and (b) those using some other property of the gas. Within these two groups there are two types, those giving continuous indications and those which analyse a sample and require some manipulation, possibly occupying several minutes.

Instruments using combustion utilise the most relevant of the properties, namely combustibility, and are sensitive only to flammable gases, so that water vapour and carbon dioxide which are usually present in the atmosphere do not interfere with the determinations. The instruments do not require air as a reference sample, but most require air for combustion so that when the atmosphere is deficient in oxygen or the gas concentration is above the flammable limit, they may not be reliable unless auxiliary air is

supplied for combustion. The range of concentration over which these instruments can operate is thus restricted to approximately the upper flammable-limits. Since the gases are burnt, the instruments must be thoroughly flameproofed. Where catalysts are used there is the possibility that they may lose their catalytic activity by poisoning or deterioration with use.

Instruments using properties other than combustion can be made to indicate over a wider range of concentration, since the flammable range of the vapour imposes no restrictions. The response is not specific to flammable gases, and the presence of non-flammable gases with similar physical properties will cause spurious readings. Many instruments, such as the interferometer and diffusion types, require fresh air for reference purposes.

One application of explosimeters is to test the atmosphere in ovens and appliances where solvents, often of high boiling point, are evaporated. In many explosimeters, the sample to be analysed is drawn through a sampling line, often several feet long, before it reaches the detecting or measuring element. Hot vapours of solvents with high boiling points may condense in the cooler line and the instrument will thus indicate a weaker mixture than is actually present. The detecting element of instruments intended for such applications should be, therefore, in the oven where no condensation can occur. This procedure has been adopted with instruments using a filament forming one arm of a Wheatstone bridge.

The use of sampling lines may also introduce errors if they are made of materials which react with the vapours. In the tests at the Joint Fire Research Organization,[16] it was found that benzene and pentane vapours were absorbed by the material of the sampling line, and it was necessary to flush the line thoroughly with air between readings. Although explosimeters are used principally in weak mixtures to indicate when the flammable-gas concentration approaches the lower flammable-limit there are many occasions when it would be an advantage if the scale indicated beyond the lower limit so that the instrument could be used in rich mixtures. An example is the use of the instrument for controlling the purging of tanks which have contained flammable gases or liquids. The atmosphere would, at first, be very rich, and then as purging proceeded would become weaker and pass through the flammable range until it became safe. The extension of the scale would permit these stages to be followed.

In solvent recovery processes, it is desirable for economic reasons to reduce the amount of air handled to the minimum, and thus the vapour concentration is as high as safety considerations will permit. To achieve maximum economy it is necessary to know the concentrations accurately. The precision required is therefore greater than is usually required of portable explosimeters.

Conclusions

Physical properties which may be used for detecting flammable gases have been widely examined. In general, methods based on these properties suffer from the disadvantage that a separate calibration is required for each compound, and the presence of other compounds with similar properties, but not necessarily flammable, may seriously interfere with, or even prevent, the detection of the flammable constituent. Nevertheless, these instruments may provide a very useful method of detecting and measuring the concentrations of a flammable gas or vapour in fixed installations, where the nature of the flammable gas and other accompanying gases is known.

Instruments using the property of combustibility, and especially those using catalytic combustion on a filament, respond to a wide range of flammable vapours and gases. The apparatus is easy to operate, can be made light and portable, and indicates the concentration of a number of vapours, with sufficient accuracy for many purposes without requiring a separate calibration for each vapour. Further work is still required on this type of instrument, since certain vapours give anomalous results, due possibly in some instances to de-activation of the filament. The solution of this problem should make the instrument applicable to the measurement of all flammable vapours likely to be encountered in industrial work.

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A NEW SMOKELESS FUEL

The chemical engineering aspects of carbonising coal at a low temperature with accompanied gas injection are discussed in this article. A summary is provided of process yields

by T. NICKLIN, M.Sc., M.Inst.Gas.E., A.M.I.Chem.E.*

THE growing public demand for a smokeless atmosphere has drawn attention to the pressing need for free-burning smokeless domestic fuel which can be used to replace coal in existing grates. Coke, which, during production, is subjected to a high finishing temperature (1000-1100°C) requires a special domestic grate for burning. For many years, however, it has been known that the solid residue from the low-temperature carbonisation of coal is more easily ignited and burns much more freely than does coke from high-temperature carbonisation, especially when coal of low rank (802), such as coal from the East Midlands coalfield is carbonised.

Because of gas demand, the gas industry has insufficient carbonising plant to provide wholly a smokeless fuel by low-temperature carbonisation, since the effect of lowering temperature is seriously to lower the gaseous output per unit of carbonising plant when compared with the normal high-temperature process. Why, then, can the North Western Gas Board now embark on the production of a smokeless fuel (Phimax) by low-temperature carbonisation? The answer is that the process of injecting gas during carbonisation, developed by the Board, together with the resulting improved heat-transfer, enables low-temperature carbonisation to be carried out without serious loss of gaseous thermal-output.

Heat Transfer in a Vertical Retort

During carbonisation under normal conditions in a vertical retort there is a continuous flow of coke from the bottom of the retort, and this flow is controlled by the rate of rotation of the extractor shown in Fig. 1. Under the influence of the external heating flues, the inside wall of the retort is at the highest temperature within the retort, and for this reason under ideal equlibrium conditions, a wedge of uncarbonised coal surrounded by a coke envelope of increasing thickness is produced. Coal throughput reaches a maximum when the lower tip of the coal wedge corresponds to the lowest heated section of the retort, since, at greater throughputs, both coal and coke would be extracted from the retort.

At the boundary between the coal wedge and the coke envelope there is an intermediate condition where the coal has become plastic in its change from coal to coke. This plastic boundary is not continuous in practice, since the movement of the charge results in continuous disruption. The plastic condition occurs at a temperature of some 600-700°C and there exists an isotherm at this boundary of the coal wedge. Furthermore, at the centre the coal wedge section is at a temperature of 100-200°C throughout the length of the wedge. Thus it can be said that the average temperature within the coal wedge is 400°C.

Heat is transferred from the inside face of the retort wall by (*a*) conduction through the coke envelope under a driving force of (*tw*−700) and a resistance which varies proportionately to the thickness of the coke envelope and (*b*) by convection from the wall to the coal in the wedge under a total driving force of (*tw*—400) and a resistance which is the sum of the reciprocals of the film coefficients of heat transfer adjacent to the wall and in the coal wedge. (*tw*=inside wall face temperature at section considered.)

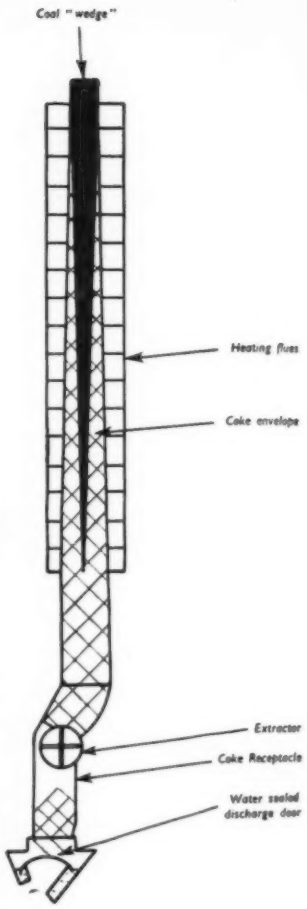

Fig. 1. Diagram of vertical retort.

Consideration of the above heat-transfer paths, which are in parallel, will show that no improvement in heat transfer by conduction can be obtained at any given temperature driving force, since the thickness of the coke envelope under equilibrium conditions is fixed by the physical dimensions of the retort.

In the case of heat transfer by convection, however, the film coefficients of convectional heat transfer will vary with the gas velocity through the retort at any section considered. The determination of the effect of increasing gas velocity, for example, by gas injection at the base of the retort, resolves itself into the calculation of film coefficients of heat transfer within packed beds, taking a large number of sections, integrating these over the length of the retort and making due allowances for the changes in gas composition and velocity which occur as gas from the coal being carbonised is added to the gas injected at the base of the retort. Results in practice confirmed that the overall heat-transfer coefficient was improved, as was to be expected, under gas-injection conditions, and this resulted in the carbonisation of increased quantities of coal per unit of plant. Throughputs were almost doubled when gas injection was practised.

Under normal conditions of operation where no gas injection is practised, the film coefficients of heat transfer at the lowest tip of the coal wedge are of the order of those calculated for natural convection, that is, packed-bed conditions, gas velocity approaching zero.

Gas injection is equally applicable and economically advantageous when it is desired to produce a smokeless fuel at a lower finishing temperature. As the total temperature driving force must be reduced in this process, the throughput of the report must also be reduced unless the

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measures indicated above for improving the convectional heat-transfer coefficient are applied. (The heat required per ton of coal carbonised in the modified process is almost the same as that required under high-temperature conditions.) The North Western Gas Board has found that the gaseous thermal output from plant producing low-temperature smokeless fuel under gas-injection conditions is only some 15% lower than when the same plant is operated under normal conditions without gas injection. Since the plant at present operating the new process represents only a small percentage of the Board's total carbonising plant, the effect of producing commercial quantities of the new fuel on the Board's gas-making potential is not pronounced. If the demand for the fuel were to increase, it would be necessary to increase the Board's potential gaseous thermal output by applying gas injection to other plant operated at normal high temperature. This would, in fact, mean merely speeding the adoption of the modification which is envisaged to meet an expanding load.

Practical Details

In converting a vertical retort to the gas-injection process it is necessary to incorporate a number of safety measures. For example, if gas were continuously injected into a retort, then when the discharge door on the coke chamber were opened there would be a serious danger of explosion. Therefore, it is arranged that the door is opened hydraulically only after the operation of safety interlocks by which injection gas is temporarily shut off and the coke chamber is purged by steam. To control the process it is necessary to have a relatively constant rate of gas injection, since a fall in the rate of gas injected would very quickly result in coal being extracted with coke by the extractor.

Fig. 2 illustrates the connections at the bottom of the retort and indicates the interlocked hydraulically-operated system which permits the safe discharge of the retort.

Process yields and efficiencies are given in Table 1. A comparison is also shown between yields obtained when producing the new fuel and when producing high-temperature coke in the conventional manner. It will be noted that the thermal efficiency of production is not substantially lower when operating at low temperatures to produce the new fuel, although the total gas produced per unit of carbonising plant is some 15% lower.

Tests have been carried out to compare the new fuel with grade 3 coal, both lighted by wood chips and paper in conventional stool-bottom grates. They show that the fuel ignites readily, burns smokelessly and takes less time to reach a useful level of radiant heat output than coal.

Table 1. Yields and Thermal Efficiencies of High- and Low-temperature Processes

	Phimax low-temperature carbonisation process using Cresswell coal with blue water-gas injection to 450 Btu/cu. ft	Normal high-temperature coke process using steam admission to produce gas having a calorific value of 450 Btu/cu. ft (from Manvers coal)
Yields (per ton of coal)		
Gas injected	21.6 therms	—
Gas from coal carbonised	47.5 therms	—
Total gas	69.1 therms	90.0 therms
Tar (5% H_2O)	16.6 gal.	18.0 gal.
Gross Phimax (wet)	11.52 cwt.	10.85 cwt.
Gross breeze (wet)	2.00 cwt.	1.55 cwt.
High-temperature coke to setting heating	1.20 cwt.	2.00 cwt.
High-temperature coke to external plant	2.50 cwt.	Nil
Thermal Efficiencies		
Thermal efficiency of production	85.4%	89.2%
(Excluding externally-produced blue water-gas)	87.9%	—
Relative Yield for a Unit of Plant (normal process = 100)		
Total gas	84.5	100
Coal throughput	110.0	100

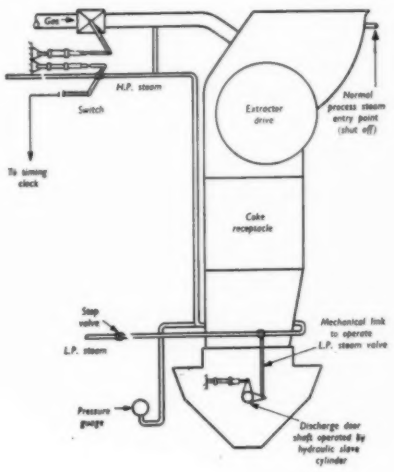

Fig. 2 (left). Retort modified for gas injection. Fig. 3. Control room showing volumetric governors regulating the injection of gas.

AMERICAN LETTER

Trade Waste Treatment in U.S.A.

DESPITE the large size of the United States in relation to the population, problems of handling trade wastes are steadily growing more acute, just as they are in Britain. In numerous instances, determined efforts to reduce stream pollution are made by the trade associations of various industries, and a typical case is the newly formed Sanitary Engineering Committee of TAPPI—The Technical Association of the Pulp and Paper Industry. This industry has already spent well over $85 million during the last ten years on pollution study and abatement, and has made much progress. Even so, a great amount will have to be done before the effluent from every mill in the country can be considered satisfactory. The new committee will help by supplying leadership, technical advice and what Kipling would call "moral 'suasion".

Lignins as Potential Fuel

One of the strongest incentives to solve a pollution problem is the opportunity to recover valuable materials in the effluent, and here the pulp and paper industry is fortunate. The average North American tree may contain 50-65% of cellulose, the balance being mostly ligneous material. In 1956, nearly 21 million tons of wood pulp were produced by various process, about 16 million tons by purely chemical means and the rest by mechanical methods. In making chemical wood pulp, the chips are digested with an alkaline or an acid cooking liquor, which dissolves the lignins and leaves the insoluble cellulose fibres from which the pulp is made. These lignins have a high combustible heat content, equivalent to as much as 9000 lb. of steam per ton of pulp produced, and this can meet the major steam requirements of the average mill. Thus, in addition to recovering some of the valuable chemicals used in the cooking process, the prospect of recovering this huge amount of potential fuel is a strong incentive to closing pulp mill circuits. Although an increasing number of successful recovery installations have already been put into large-scale operation, the scope for improvement is still great. Many mills, of course, have installed Saveall machines for removing valuable cellulose fibre from white waters and other effluents, since this is a straightforward operation that offers an immediate return, quite apart from any reduction of stream pollution.

Let us take the example of the sulphite pulp industry. Last year, about 2,664,000 short tons of sulphite pulp were produced in the U.S.A., and though this was less than 15% of the nation's total pulp production this output carried with it a very considerable effluent problem. It has been estimated that from this process alone the daily total of spent liquor amounts to some 33 million gallons, which contains about 10,000 tons of lignins, plus chemicals equivalent to the 1000 tons of lime and 675 tons of sulphur used in the production of the cooking liquor.

Here, then, is a trade waste problem of vast size. The methods developed to overcome pollution from this source are interesting, as they combine heat recovery with partial or near-total chemical recovery. These methods involve problems in chemical engineering and metallurgy.

The sulphite pulp process was invented by the Tilghman brothers of Philadelphia in 1866, and was developed on a successful practical scale by Ekman and Fry in Sweden about 1871. It depends upon the digestion of wood chips with calcium bisulphite liquor. After the digestion process has been carried out, it has been the practice to discharge the spent liquor and washings into the nearest local river, a practice that can have adverse effects miles downstream. Attempts to recover the spent liquor by concentration led to serious scaling difficulties, owing to the insoluble calcium salts formed in the evaporator and other parts of the system. Furthermore, when the concentrated liquor was burned to recover the combustible heat, a fly ash of unusable calcium sulphate resulted, and the whole recovery process came to be regarded in America as uneconomic; as a result, dumping of the spent liquor continued.

After much study on the part of the sulphite pulp industry, chemical suppliers and plant manufacturers, two successful solutions to this complex problem were found. These are now being operated all over the U.S.A. Both solutions involved not merely an addition of effluent treatment plant, but certain fundamental changes in process operations. It has been claimed that these processes also result in reduced digesting and washing times; in addition, the pulp produced is of better quality. One of these modified methods is the ammonia-base sulphite process, and the other the magnesia-base sulphite process.

In the ammonia-base process, the cooking liquor consists of sulphur dioxide dissolved in aqueous ammonia. This has the advantage of giving soluble salts which do not cause serious scaling difficulties on evaporation; moreover, the concentrated spent liquor can be burned for steam generation. Unfortunately, the ammonia radical cannot at present be economically recovered, but future developments may achieve that desirable objective. The sulphur, however, can be partially recovered and re-used to make sulphur dioxide. Alternatively, the spent liquor can be concentrated and used as a road binder; alternatively, it can be spray-dried, to yield a material valuable as a fertiliser or as a source of numerous chemicals. The mill liquor circuit can thus be completely closed, to give freedom from harmful stream pollution, valuable heat recovery and partial sulphur make-up. Furthermore, the process has the added advantage that an existing calcium bisulphite liquor system can be converted fairly simply to ammonia-base manufacture, so that the additional capital expenditure is not great.

Advantages of Magnesia Process

The magnesia-base process, on the other hand, does involve the installation of much new equipment. At the same time, the recovery of chemicals used for liquor making is much greater, which offsets the higher investment involved. In this process the cooking liquor is made by absorbing the sulphur dioxide in a slurry containing about 10% of magnesium hydroxide. After digestion, the spent liquor is evaporated and burned to raise steam for the mill. Under controlled conditions the products of combustion are soluble magnesia and sulphur dioxide, both of which are largely recovered for use in making fresh liquor on a continuous basis.

The system is thus completely closed and stream pollution again eliminated. It is of interest to mention that the world's very first sulphite mill—that organised by Ekman and Fry—first of all used a magnesia-based liquor. Its high cost, compared to a liquor based on limestone, proved prohibitive, as the engineering problems of magnesia recovery proved too difficult at that time.

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Nomogram for Sizing Drum and Disc Filters from Leaf Test Data

(1) The basis is Equation (4) in Part II of "The Sizing of Rotary Vacuum Filters" (see p. 196 this issue).

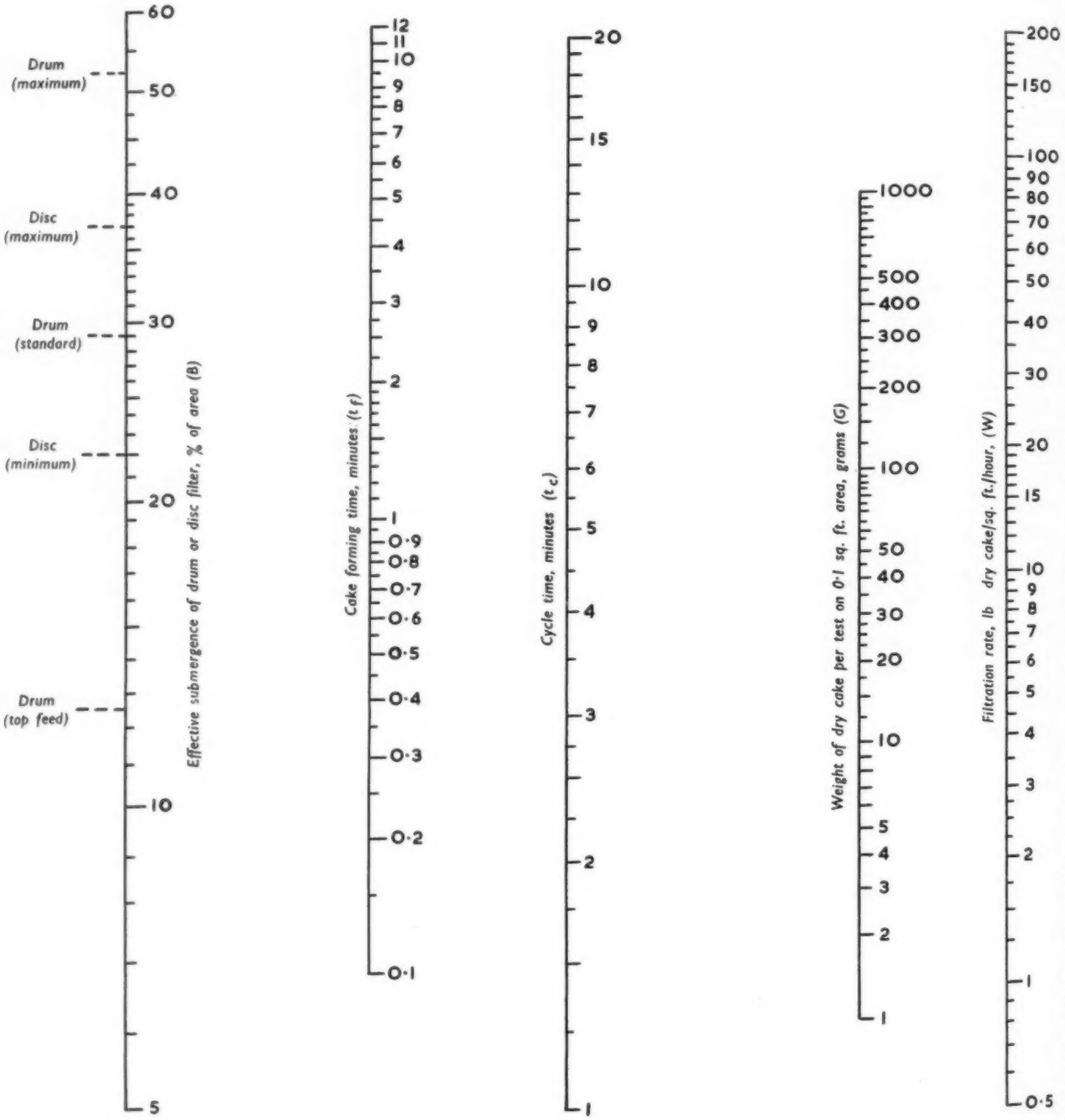
$$W = 0.001057 \frac{GB}{t_f A} \text{ lb/sq. ft/hr.}$$

Since the standard filter leaf is 0.1 ft² area, the equation reduces to:

$$W = 0.01057 \frac{GB}{t_f}$$

(2) Check calculation shown where $B = 29\%$, $t_f = 1$ min., $G = 70$ gm.
∴ by nomogram, $W = 21.2$ lb/ft²/hr.
by equation, $W = 21.4$ lb/ft²/hr.

(3) On the % effective submergence scale are shown positions for the *drum filter* (top-feed, standard submergence bottom feed, and maximum submergence bottom feed) and the *disc filter* (maximum submergence which requires trunnion stuffing-boxes, and minimum submergence which is the standard design). These points are not precise, since they depend upon the size of the filter: thus the margin between apparent and effective submergence decreases as the size of the unit increases; they do, however, represent reasonable averages for the size of filters normally used in the chemical industry.



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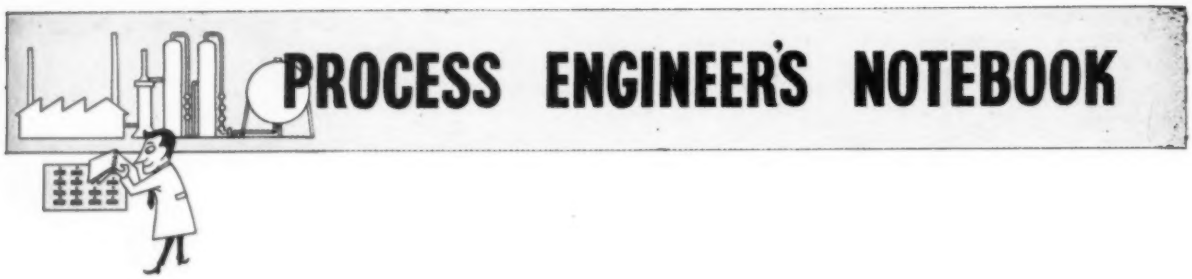
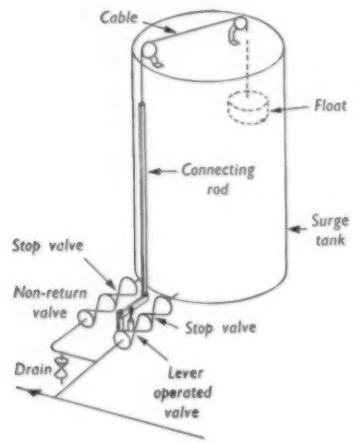


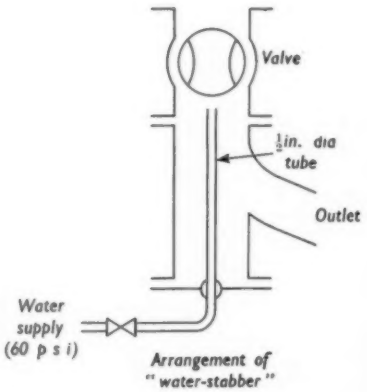
Preventing Surge Tank Spillage

THE SCHEME DESCRIBED is intended to prevent overflowing from surge tanks. Its essential parts are separate inlet and outlet branches connecting the tank to the main pipeline. In one branch there is a lever-operated valve which stops flow into the tank when it is nearly filled; in the other a swing check valve which allows the liquid to drain back to the main line. The movement of the lever-operated valve is controlled by a float connected to the valve lever by a rod cable-pulley system. The float comes into operation when the liquid level in the tank approaches the top, and when it is not floating its dead weight is sufficient to keep the lever-operated valve



open. In these circumstances, flow will take place into the tank through this valve. As long as the head pressure in the tank exceeds the line pressure the check valve will remain open, otherwise it remains closed. When the level rises the float movement will eventually cut off the flow to the tank. The liquid will discharge through the check valve when the line pressure falls below that corresponding to the head of the liquid in the tank, and the float-controlled valve will again come into operation when the liquid level in the tank falls.

Clearing Discharge Outlet Blockages



Arrangement of "water-stabber"

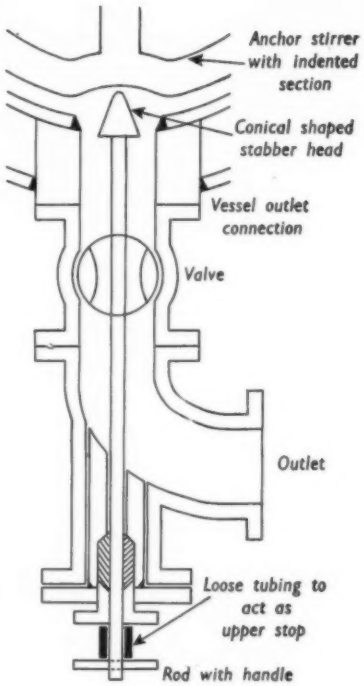
WITH REGARD TO THE USE of rodding-through devices on the discharge outlets of vessels (*British Chemical Engineering*, 1956, **1**, 442), the stabber head should be arrow-, spear- or conical-shaped to facilitate penetration of the accumulated solids. This type of head eliminates the need for a retainer pin to act as a lower stop.

Precautions must be taken to ensure that the stabber does not come into close contact with any stirrer in the vessel, yet it should penetrate a short distance beyond the vessel bottom to clear adequately any blockage. A simple but efficient upper stop is a loose piece of metal tubing of predetermined length, fitted over the shaft at the handle-end, which stops at the gland housing. This also saves trapping the operator's fingers between the handle and the gland. Anchor stirrers, incidentally, can be obtained with the lower section near the vessel outlet and indented to allow for the penetration of the stabber. The indentation allows the rest of the stirrer to be in close clearance with the wall of the vessel.

However well designed, stabber glands tend to leak during discharge from the vessel, and this can be most undesirable if the liquor is corrosive or expensive. In cases where a slight aqueous dilution of the charge is of no consequence, it is often worth considering the fitting of a "water stabber". It consists simply of an upward-directed jet (connected to, say, a 60 psi water supply) located inside the valve housing. During its brief operation, it is an easy matter to block temporarily the main outlet if so desired. Such an arrangement is simple and clean to use, and extremely efficient with loose slurries.

Careless stabber operation can cause severe damage to plug-cocks, and it is surprising that rubber pinch-cocks are not used to a greater extent. These are readily supplied, simple in construction, neat in appearance and, above all, cheap. Rubber inserts can be obtained to withstand most conditions of acidity, alkalinity, and hydrocarbon solvents. Their use often eliminates the need for a stabbing device, yet stabbers, both of the conventional rod-type or water-type, are readily adaptable.

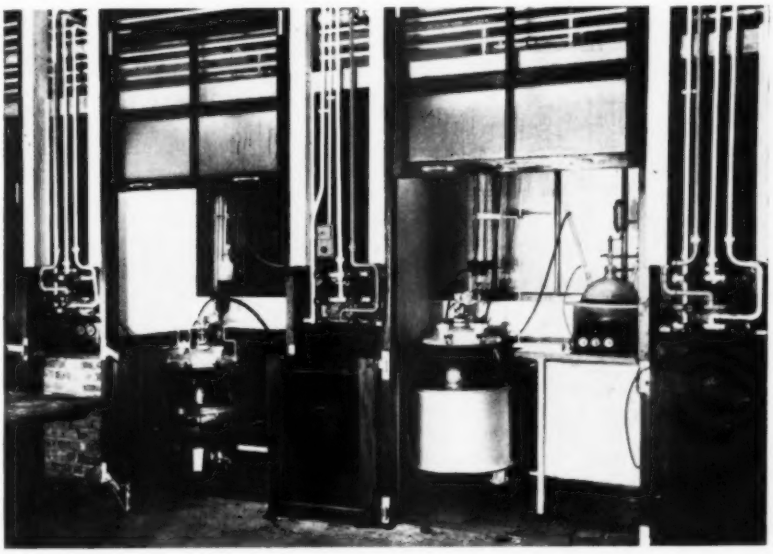
J.W.M.



Cabinet for Small-scale Manufacture of Organic Chemicals

THE ILLUSTRATION SHOWS a cabinet in which small-scale manufacture of organic chemical reagents is carried out. The reactions themselves are generally of an unpleasant character, requiring the handling of liquids that fume readily on exposure to the atmosphere and which evolve unpleasant fumes in quantities that make recovery uneconomic but sufficient to be a nuisance or a danger to the operating staff. The cabinets are designed to give ready access to the equipment—note the half-doors and windows of protected glass. The cabinets are connected to an induced-draught system for removal of fume and gases, which are then disposed to the atmosphere via a high plastic chimney.

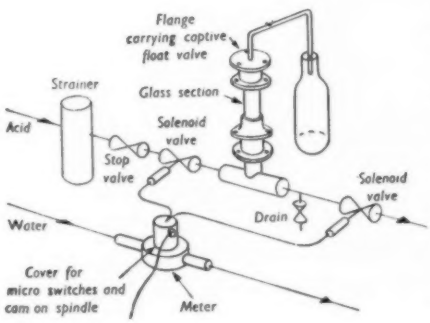
The services to the vessels, such as steam, water, compressed air, vacuum, brine and electricity, have their various manual controls fitted outside the cabinet. The operator, therefore, can look after a reaction in comfort and safety. A number of cabinets of this type are installed at the Poole works of B.D.H. Ltd., through whose courtesy this item appears.



Simple Water-dosing System

THE ATTACHMENT of a cam and a pair of microswitches to the spindle of a rotary water-meter can provide the starting point for a simple system of intermittent dosage of the water passing through the meter.

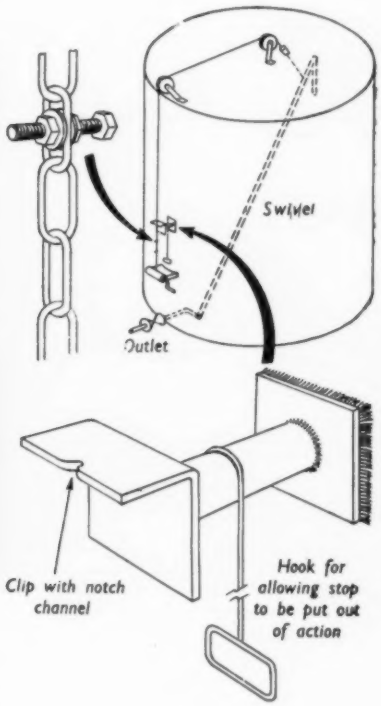
The chemical dosage section contains a glass tube attached to a tee-piece, at either end of which is a magnetic valve. Each of these is connected to the microswitch mounted on the water or main flow-meter. The tee-piece assembly is proportioned to give the amount of chemical required by the amount of water represented by half a complete revolution of the meter spindle. For example, if a revolution of the slower rotating spindle corresponds to 1000 gallons, then the tee section must be made to hold a volume equal to the quantity of acid or other treatment chemical required to treat 500 gallons of water. The solenoid valves enclosing the glass section close with current failure. The cam movement ensures that when one valve is closed the other must be open. The cam is shaped to cause either switch to be off just long enough to allow the contents of the metering section to discharge or fill completely. Air is expelled through a vent which is closed by a small captive float-valve when the level of liquid rises in the glass. D.M.M.



Avoiding Blockages in Storage Tank Exit Connection

IN ORDER TO AVOID blockages in the outlet pipes of tanks fitted with swivel dip-pipes, it is necessary to prevent the open end of the swivel pipe from dipping into the sludge at the bottom of the tank. With winch-operated swivels the problem can be overcome by fitting to the side of the tank a clip with a shallow notch cut in it to allow the winch chain to pass through. Upward movement of the chain and downward movement of the swivel is prevented by attaching a stop to the chain. A bolt threaded through a chain link is a simple form of stop. The bolt is made secure at that position in the chain whereby the open end of the swivel is well clear of sludge. If a lower position of the dip-pipe is required the chain and bolt can be pulled clear of the forked clip by a hook, thus allowing the chain to be raised further from the winch.

If a cable is used instead of chain, a cylindrical clamp type of stop must be used instead of a bolt. In this case, the clamp will have to be thin and also short enough to allow the cable to be wound on the drum of the winch.



Book Reviews

The Metallurgy of Zirconium

Edited by Benjamin Lustman and Frank H. Kerze

National Nuclear Energy Series, Division VIII, Volume IV. McGraw-Hill, New York and London. 776 pp., 75s.

THIS book provides a critical presentation of the many and various aspects of zirconium technology, and contains much information derived from A.E.C-sponsored investigation on this metal which is becoming so important in the nuclear engineering field.

The chapter dealing with methods of production provides a detailed account of the working of the Kroll process, written by workers who took an active part in its development. In addition, this chapter includes a section on other production processes. Of these, the most interesting is the Fusion Electrolysis of Chloride or Fluoride Baths. It is concluded that although the electrolysis of fused salts produces a metal of acceptable quality, the process does not possess any real advantage over other methods of production, particularly as the metal is produced as a powder and the cell is operated batch-wise.

The iodide process—the only other method of commercial production—has a chapter all to itself and is well covered. Noteworthy here is the description of the operation of the plant of Westinghouse Atomic Power Division. This plant was built to purify the Kroll sponge produced at the U.S. Bureau of Mines unit; subsequently it was found possible to avoid this expensive purification treatment, but the operations at Westinghouse provide a fine example of the drive, courage and determination of U.S. technologists. The Foote Mineral Co. had operated an iodide plant for many years, and some idea of the work done at Westinghouse can be gauged by the fact that the plant at Foote consisted of small Inconel units 9 in. in diameter and 24 in. long, each capable of producing 6 lb. "crystal" bar per run. The units employed at Westinghouse were 2 ft in diameter and 5½ ft long and produced a deposit weighing as much as 117 lb. Attempts to develop a continuos iodide process are described; all these failed, however, and it was concluded that the technology of the handling of corrosive solids and gases at high temperatures under high vacuum requires further study before this type of production had any hope of success.

Potential users of zirconium will be most interested in Chapters 10 and 11 dealing with (a) the mechanical properties and (b) the corrosion of zirconium and its alloys. The first of these chapters includes a warning that in assessing the mechanical properties of the metal it is necessary to ascertain the annealing history and the sources of contamination of the material tested.

Of particular interest to nuclear workers is the discussion of corrosion in water and steam. The author of this section is D. E. Thomas of Westinghouse's Atomic Power Division, where so much of the corrosion-testing of zirconium in water at high temperature has been done. G.L.M.

Aspects of River Pollution

by Dr. L. Klein

Butterworths Scientific Publications, London, 1957, 621 pp., 84s.

MANY manufacturers and local authorities at present discharging liquid effluents to surface waters, and causing thereby varying degrees of pollution, will be required to take remedial action when the provisions of the 1951 Rivers (Prevention of Pollution) Act are further implemented. The Act encourages rivers boards to establish by-law standards for the control of such discharges but no board has yet done so, although six of the seven years of grace allowed for this purpose have now expired. This respite has been welcomed by industry, but not the continuing uncertainty about its future obligations and the possibility of finding practicable and economical means of meeting them. There has been, on this account alone, a real need for an authoritative appraisal of the present, rather confused position and this has now been admirably met by the publication of Dr. Klein's comprehensive survey of British practice in this field.

The author of this important work is well qualified for the task. He has had practical experience with the Manchester Corporation Rivers Department of the treatment of sewage and trade wastes, and as Chief Chemist, first of the old Lancashire Rivers Board and now of the Mersey Rivers Board, he has for many years been actively concerned with the disposal of effluents from an area which includes industrial South Lancashire.

After opening chapters outlining the historical and legal background, subsequent sections deal in greater detail with the nature, effects and causes of pollution. The chapters on the detection and measurement of pollution and on methods in use for the purification of sewage and trade wastes are intended to add completeness to the book rather than to amend or encroach on existing publications that give more exhaustive treatment.

Sections on general biological aspects and the effects of pollution on fish are contributed respectively by Mr. H. A. Hawkes of the Birmingham, Tame and Rea District Drainage Board and Dr. J. R. Erichsen Jones of the University College of Wales.

The most controversial section of the book is that dealing with standards of purity. Although limits for sewage effluents based on the recommendations of the Royal Commission are generally acceptable where the prescribed dilution is available, recently proposed supplementary standards for sewage and trade effluents have been critically received. The author summarises Royal Commission recommendations and discusses the working standards used by various river boards. He outlines the reasons for the adoption by the Mersey Rivers Board of the putrescibility and the 10 ppm nitrate minimum limits for sewage effluents. It is of interest that a successful appeal against the latter requirement has recently been made to the Minister. Separate standards for sewage and trade wastes are favoured with relaxation where difficult wastes are receiving treatment by the best practicable and reasonably available means. Because of the greater ease of enforcement, effluent standards are preferred to river standards, though some form of stream classification according to the use which is to be made of the water appears unavoidable.

The insufficient attention which is directed to the serious and increasing threat to industry of actions based on Common Law is unfortunate. A single fisherman, by such action, can be instrumental in the closing down of an important factory *even when the effluent from it conforms to the requirements of statute law.*

As the overloaded sewage works cause by far the most widespread pollution, and as the immediate reconstruction and extension of all such works would involve a rate of capital expenditure which would overstrain the national economy, spectacular progress towards the solution of the problem is not to be expected. Much can, however, be accomplished by the education of offenders to appreciate the harmful effects which waste matter can have on river life and the existence of satisfactory and economical methods for the purification of many varieties of industrial effluents. Dr. Klein's book will form the standard text in this form of education for some time to come.

I. S. WILSON

CHEMICAL ENGINEERING PRACTICE

under the
General Editorship
of

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Indian Industrial Control

The Industries (Development and Regulation) Amendment Act, 1956, which has received the Indian President's assent and will come into force on a date to be appointed by the Government of India, adds 31 new industries to the existing schedule of 42 industries already under the control of the Indian Union Government. The Schedule has been rearranged so that the controlled industries are grouped together on a scientific basis. When the Amendment Act comes into force the First Schedule will include the following products and industries:

Industrial Machinery: (*A*) Major items of specialised equipment used in specific industries, including chemical and pharmaceuticals machinery. (*B*) General items of machinery used in various "unit processes", including size reduction equipment—crushers, ball mills, etc.; size separation units—screens, classifiers, etc.; mixers and reactors—kneading mills, turbo mixers, etc.; filtration equipment—filter presses, rotary filters, etc.; centrifugal machines; evaporators; distillation equipment; crystallisers; driers; power-driven pumps—reciprocating, centrifugal, etc.; air and gas compressors and vacuum pipes (excluding electrical furnaces); and refrigeration plants for industrial use.

Industrial instruments: water meters, steam meters, etc; indicating, recording and regulating devices for pressure, temperature, rate of flow, weights, levels and the like.

Fertilisers: inorganic, organic, mixed.

Chemicals (other than fertilisers): inorganic and organic heavy chemicals; fine chemicals including photographic chemicals; synthetic resins and plastics; paints, varnishes and enamels; synthetic rubbers; man-made fibres; coke oven by-products; coal tar distillation products; explosives; insecticides, fungicides and weedicides.

Dyestuffs.

Drugs and pharmaceuticals.

Fermentation industries.

Soaps.

Japan to Make Polyester Fibre

I.C.I. have concluded an arrangement with Teikoku Rayon Co. and Toyo Rayon Co. under which these companies will acquire patent rights for the manufacture of polyester fibre in Japan. The arrangement will involve a substantial fixed payment and a continuing royalty on sales. The Japanese companies will not have the right to export polyester filament yarn, staple fibre and film to the United Kingdom or to any other country in which relevant patents exist.

A New Hard Material

A material which is harder than diamond has been produced experimentally by the U.S. General Electric Co., using high-pressure equipment that was employed in 1956 to make artificial diamond. The new material, Borazon, is made from boron nitride, and can withstand considerably higher temperatures than diamond, remaining solid and physically unaffected at temperatures of 3500°C. Borazon is said to be only the forerunner of a whole range of new materials of potential industrial importance that is expected to be produced as the result of this high-pressure research.

Increased Citric Acid Production

The first stage of a £250,000 expansion scheme started by John & E. Sturge, of Birmingham, and designed to increase their output of citric acid by 70% has been completed. The final stage will now be completed by March, 1958, instead of by January, 1959. It is being claimed that the extra citric acid then available to U.K. consumers will considerably reduce the need to pay the higher prices prevailing abroad.

Norwegian Refinery

The Standard Oil Co. proposes to construct an oil refinery on the east side of Oslo Fjord, Norway. The refinery will cost some kr. 215 million and will have a processing capacity of about two million tons of crude oil a year. It is hoped that work on the refinery, which, when completed, will be the largest in Scandinavia, will start in 1958 and be completed and in production by 1960.

Japanese-Burmese Merger

It is reported that the Burmese Industrial Mission in Tokyo has reached an understanding with leading Japanese fertiliser firms on the establishment of a joint chemical fertiliser factory in Rangoon. The initial target of this joint venture is said to be some 50,000 tons, mostly phosphate and nitrogenous manure, rising eventually to an annual output of 100,000 tons.

Swedish Chlorine Plant

A new chlorine and caustic soda factory is now being built at Strömsbruk, in Central Sweden. The plant is being built for Ströms Bruks A.B., wood goods, pulp and wallboard manufacturers, and is expected to start production this year.

Rise in Lead Production

Production and export of Honduras lead is increasing after a period of inactivity in the industry, and, during last year, it is thought that more than 4 million lb. of the metal was exported.

Record Production Figures

Record production and distribution figures were achieved by the Indian firm Fertilisers and Chemicals (Private) Ltd. during 1956. Production of ammonium sulphate for the year exceeded the target of 330,000 tons by 1725 tons, giving an average production of 906 tons a day, which is the highest yet achieved. Production of ammonia for the year 1956 was 94,443 tons, and that for ammonium sulphate was 373,021 tons, both being the highest yet recorded.

Record Plastics Output

Output of plastics in Britain during 1956 reached a record value of 335,000 tons, and was double that during 1950. The 1956 increase (10,000 tons), however, was slightly less than the increase in output between 1954 and 1955. Thermoplastics materials, including PVC, polythene and polystyrene, were again responsible for more than 50% of the output.

Mexican Soda Production

A half interest in Productos Quimicos Mexicano S.A., producers of caustic soda, has been brought by Dow Chemical, and plans are in hand to double the capacity of the Mexican company's plant.

Vulcanising by Radiation

Research workers of the B. F. Goodrich Co. have succeeded in vulcanising a tyre by atomic energy—an advance, the company claim, that is the first change in the curing of rubber products for over 100 years. It may not be commercially feasible, they say, for ten years. Experiments indicate that the atomic-cured tyre has from 8 to 10% more resistance to abrasion than the conventional tyre and twice as much resistance to ageing and deterioration. The tyre was vulcanised at the A.E.C.'s National Reactor Testing Station, in Idaho, by being placed in a steel mould and rotated slowly over radioactive fuel elements from the reactor.

In Britain, work in the same field is being conducted by the Dunlop Rubber Co. in their irradiation laboratory opened last year. The laboratory can accommodate a 100-curie source of cobalt 60, a source of about 1000 curies. The installation of an electron accelerator has not been ruled out.

Polythene and Nylon Tubing

The general extrusions technical committee of the British Plastics Federation is considering a specification for high-density polythene tube for cold-water services, and is also investigating the future possibilities of the use of special grades of nylon tube for hot-water services.

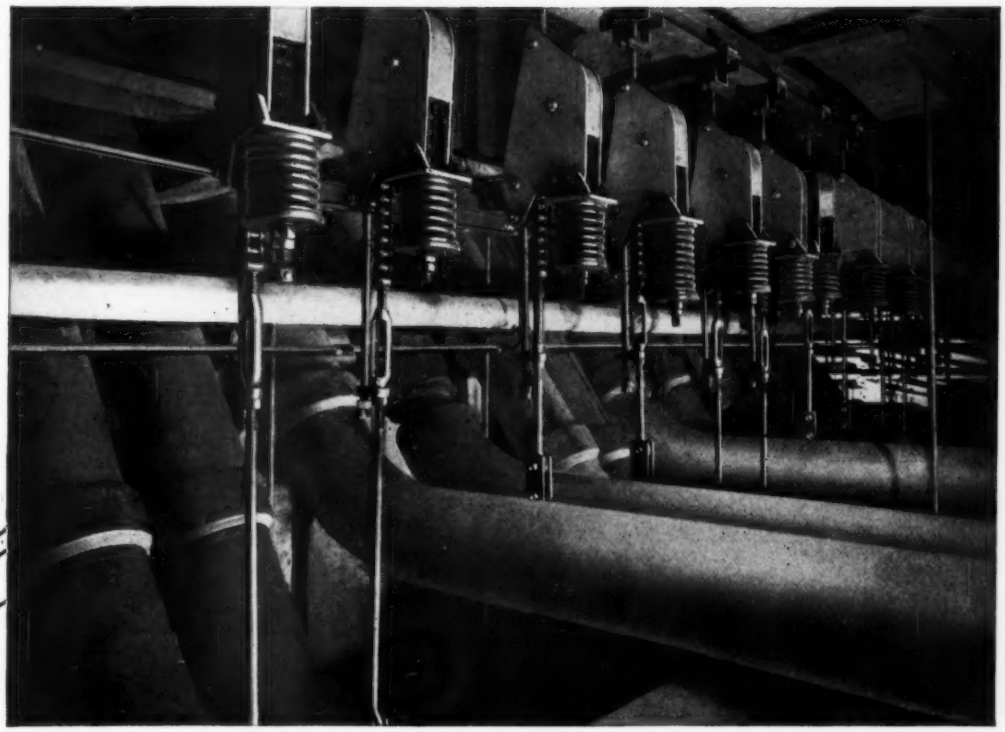
Projects for U.S. Designer

Two ammonia synthesis separation plants, a urea plant in Japan and an ammonium sulphate-from-gypsum plant in Italy, are to be designed by Chemical Construction Corp. of U.S.A.

Wolfram from Turkey

A protocol was signed at Ankara recently between the Etibank and Krupps relating to the exploitation of the wolfram deposits discovered at Uludag, near Bursa. The deposits are estimated at 10 million tons and the annual production from them should be 180 tons of wolfram concentrate. Krupps will provide machines and equipment.

Constant TENSION



P.F. Coal Pipes at Tilbury Power Station
Photograph by courtesy of the C.E.A.

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High-pressure steam piping is subject to wide variations in temperature, which produce considerable expansion and contraction. Unless the pipe supports can absorb and compensate for this movement, severe stresses are set up which may result in fracture. The "Con-Ten" Pipe Support is designed to cradle any type of piping with constant tension under all conditions, throughout the range of movement. "Con-Ten" is installed, with eminently satisfactory result, in power stations, oil refineries, chemical and industrial plants throughout the world.

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PLANT EQUIPMENT NEWS

Axially-ventilated Motors

English Electric have introduced a new class, the C range, of axially-ventilated electric motors in ratings from ½ to 50 h.p. The motors are built to the standard fixing dimensions of the new British Standards draft specification CW(ELE) 6246. They use class E insulation, which permits a temperature rise of 65°C on 40°C ambient temperature. For a given rating the machines are therefore smaller, lighter and cheaper than those of previous designs which permitted only a 40°C rise. The motors are available as protected or drip-proof models. Although the maximum temperature for the winding is 105°C, the frame surface-temperature will not normally exceed 90°C in free air. The conductor wiring is covered with an enamel based on polyvinyl-acetal resin. **The English Electric Co. Ltd., Marconi House, London, W.C.2.**

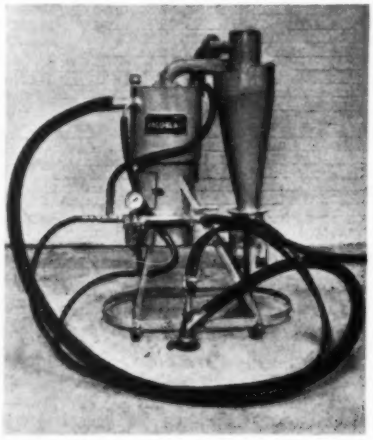
BCE 1086 for further information

Carbon Ejectors

Powell Duffryn are now offering a range of water- and steam-operated carbon ejectors. The equipment is capable of handling at high rates all corrosive fluids and is particularly suitable for waste pickling liquors contaminated with crystals, shale, etc. With the water-operated types, water with a pressure as low as 5 psi may be used and waste liquor can be discharged directly to

neutralisation plant or to waste. The ejectors have been designed for high mechanical and thermal robustness, and they contain no moving parts. All carbon parts are completely protected by the cast-iron casing. The standard size of water-operated ejector has a capacity of 5000 gal. an hour. **Powell Duffryn Carbon Products Ltd., Springfield Road, Hayes, Middlesex.**

BCE 1087 for further information



Mill-scale Gun

The new Vacu-Blast high-production gun has been constructed for removing mill-scale from flat, horizontal steel-plate at a high rate prior to fabrication. The gun is used in conjunction with a Vacu-Blast continuously-cycling, mobile, shot-blast machine, and it can be operated manually or be mounted in a self-propelled, variable-speed gun carriage. A blast-cleaned track, 8 in. wide, is obtained with each pass of the gun, and mill-scale can be removed at an average rate of between 300 and 600 sq. ft per hour, depending upon the condition of the surface to be blasted. In effect, the gun is a small blast-cabinet in which is fitted a rotating nozzle-assembly consisting of three ¼-in. blast jets. Abrasive shot from the machine is directed through the jets on to the work-surface with great force. Vacuum pick-up then returns the abrasive, together with the removed surface deposits, to the machine where shot is separated from the debris and returned to the gun. **Vacu-Blast Ltd., 291 Aberdeen Avenue, Slough, Buckinghamshire.**

BCE 1088 for further information

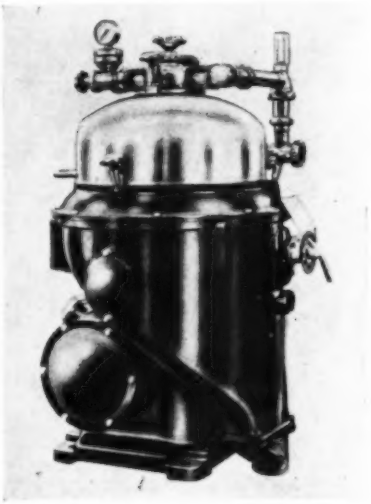
A New Salinometer

The Cossor model 1435 salinometer has been designed to eliminate the need for routine checks on boiler-house water for salt content. The principle of operation is the increase of electrical conductivity of water with the increase in salinity. A low-frequency alternating potential is applied to two electrodes placed in the main water feed and, if the current passing through the solution exceeds a predetermined value, a safe light is extinguished and an alarm bell and light are switched on. The alarms operate also if a fault develops in the instrument. Reliable working under conditions of vibration and high ambient temperature has been assured, the makers say, by rugged construction, generous temperature rating on all components and careful choice of materials used. The instrument is set normally to indicate alarm at 200 units conductivity, i.e., 8 gr./gall. or 115 mgm./l at a distillate temperature of 200°F. **Cossor Instruments Ltd., Highbury Grove, London, N.5.**

BCE 1089 for further information

Self-opening Separator

The new De Laval self-opening separator, type PX 209-00S, has been introduced for use in the chemical, food and other process industries. It is a modification of the company's established self-opening separator, and has a constant-capacity disc-type bowl for either liquid/solid or liquid/liquid/solid separation. By the use of a hydraulic mechanism, solids may be ejected while the bowl is running at full speed. Stoppages for bowl cleaning are thereby elimnated and the machine can be used for



fully automatic processes. The bowl opening may be controlled manually or automatically with a timing device. All parts of the machine that come into contact with liquid are made of stainless steel. The separator may be either gravity or pump fed, and the clarified liquid can be discharged to a height of 60 ft without additional pumping. A flowmeter, sight glasses and pressure gauge are fitted as standard equipment. **Alfa-Laval Co. Ltd., Brentford, Middlesex.**

BCE 1090 for further information

Flow-control Equipment

The Flostat now being manufactured by Platon is a self-acting flow controller combining a flowmeter and a valve, both operated by the pressure energy of the fluid. In appearance, it resembles a valve and fits directly into a pipe-line. In operation, it is said to deliver fluid within 1% of the set rate, irrespective of variations of fluid pressure upstream or downstream. The design features include a double-beat valve which is pressure balanced to achieve high sensitivity and

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The Super-D-Canter does the complete job

The casein discharged from this first operation contained about 3 per cent ash on a dry (moisture free) basis. To deal with installations where the highest purity casein is required, we developed a further process of acid treatment followed by separation in a second stage Super-D-Canter.

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Write to us and we'll be glad to send you a copy of our Report No. 2956M—Applications of the Super-D-Canter. Or, if you wish, 'phone Camberley 2601 and talk to Martin Trowbridge about your problem.

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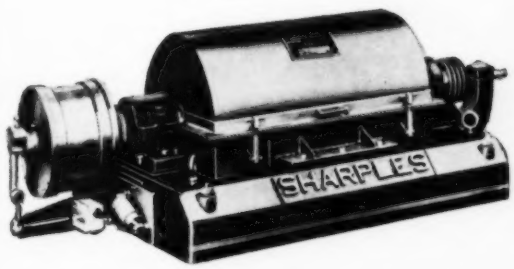
SHARPLES



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PLANT EQUIPMENT NEWS

response speed; in fact, a recovery time often as short as 0.5 second is claimed. The flow-setting can be altered widely by changing the orifice size and altering the bellows fixing to the valve stem. A flow-scale can also be provided. **G. A. Platon Ltd., 323a Whitehorse Road, Croydon, Surrey.**

BCE 1091 for further information

Protection of Chimneys

Metalife ATR is a new liquid metallic-coating for use in the rustproofing of steel surfaces that are subjected to high temperatures; for example, steel chimneys. It is said to withstand temperatures up to 550°F. The coating is applied cold by a brush or spray gun and it dries to leave an anodic metal skin, which gives cathodic protection to the chimney. Tests carried out for the manufacturers have shown that annual repainting with the new coating is unnecessary. **Southern Metalife Ltd., James Street, Harrogate, Yorkshire.**

BCE 1092 for further information

Vacuum Filter

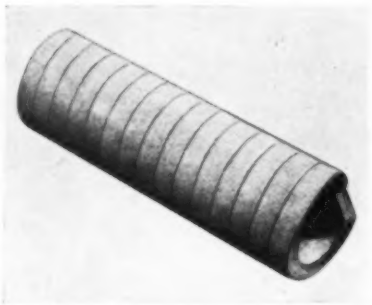
Vacuum filters, made from Resilon synthetic - resin - bonded fibre - reinforced material, are now being made by Russell Constructions. They are said to be immune from hair cracks, to be stable under sudden changes of temperature, light in weight yet sufficiently strong and resilient to withstand vigorous handling and to provide a long working life. They

are constructed in five units—a top section comprising a cylinder having a capacity of 30 gal.; a bottom section consisting of a spherical and a cylindrical casting with a side outlet for connection to a vacuum circuit; a perforated plate 27 in. in diameter; and gaskets. The weight of a filter is 102 lb. **Russell Constructions Ltd., 8 Adam Street, London, W.C.2.**

BCE 1093 for further information

Plastic Gland Packing

A new gland packing, Superlon, which has been developed by Crane Packing incorporates the chemically-inert plastic, Fluon. It contains no metallic constituents or graphite and can be used safely, the makers say, on services handling food products. The packing will withstand the action of water, steam, oils and solvents and other chemicals, including acids in



moderate concentrations. Its working range of temperatures is from −40° to +500°F. **Crane Packing Ltd., Slough, Buckinghamshire.**

BCE 1094 for further information

Laminate Fabrication

Laminates made from bakelite, epoxide and polyester resins reinforced with glass-fibre materials are now being used by Mendip Chemical Engineering for the fabrication of chemical plant. One of the useful qualities of the laminates for plant construction is their chemical resistance. In addition, they have a high strength-to-weight ratio, their resistance to abrasion can be heightened, if required, to meet particular conditions, and they may be formed readily into structures of complex shape. **Mendip (Chemical Engineering) Ltd., Feltham Road, Ashford, Middlesex.**

BCE 1095 for further information

New Generator

Servomex are producing a new low-frequency waveform generator, type LF.51, of British design for testing automatic control systems. For electric systems it can be used directly, and the frequencies it provides cover the range that is of interest in the automatic control field. With its use it is possible to carry out sine-wave testing and then, without altering the connections, to change over to a very wide range of impulsive functions. **Servomex Controls Ltd., Crowborough Hill, Jarvis Brook, Sussex.**

BCE 1096 for further information

Rotary Louvre Cooler

A new cooler is being introduced by Dunford & Elliott, in which the material is moved by rotary louvres and water is used as the cooling medium. The illustration is of a two-stage cooler of this kind with its outer shell cut away to show the internal construction. The two drums

are partly sectioned to indicate the relationship between the cooling louvres, the bed of material being cooled and the circulating water. The drums revolve slowly on a horizontal axis and collect water in their hollow, tapering louvres from a water bath in which they are partially immersed. The collected water flushes along the louvres against the movement of the material, so producing good heat transfer. When handling materials containing moisture which will evaporate during cooling, low-velocity air can be passed through the cooler. The equipment is manufactured in one, two or three stages and in a range of diameters and lengths. It is suitable for most crystalline or powdered materials, provided they are not sticky. The parts in contact with the materials being cooled are made normally of mild or stainless steel or aluminium, and the water bath and its enclosures are of galvanised mild steel. **Dunford & Elliott Process Engineering Ltd., Linford Street, London, S.W.8.**

BCE 1097 for further information

Plastic Extruders

General Engineering have developed a new range of screw-type extruders for plastics and rubber. The machines are driven by an externally-mounted variable-speed motor, rated, like the machine, for continuous duty. This is coupled to the extruder through a vee-belt drive. Worm reduction-gearing is incorporated and the thrust bearing assembly has been kept separate from this to prevent any thrust loads being transmitted to it. **The General Engineering Co. (Radcliffe) Ltd., Station Works, Radcliffe, Lancashire.**

BCE 1098 for further information

Metal Stoppings

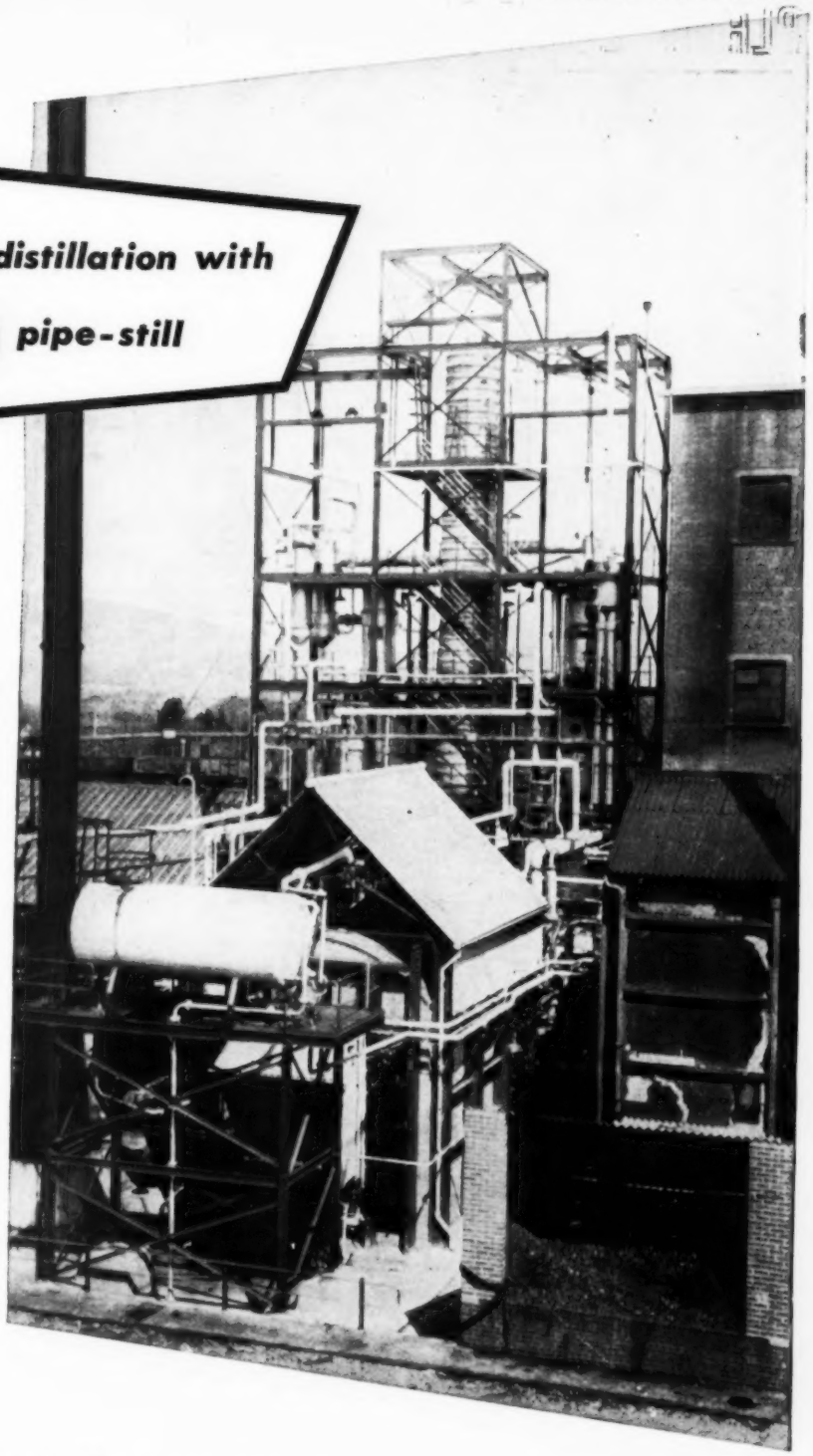
Two epoxide resin-based metal stopping compounds have been developed by Lucent Products. They can be used, it is said, to fill holes up to 2 in. deep at one filling; they shrink by about only 0.01% and will bond to most materials. The tensile strength of the compounds is of the order of 10,000 lb., but they are not suitable for use at temperatures above 55°C when cured. **Lucent Products Ltd., Oaklands, Clayton Road, Chessington, Surrey.**

BCE 1099 for further information

Sleeve-packed Cocks

Klinger are making available a new assembly of sleeve-packed cocks which has been specially designed and manufactured for the U.K. Atomic Energy Authority, and has been installed in the pile at Calder Hall. The assembly consists of three-way cocks ganged together in the form of an eight-unit cock-

CONTINUOUS tar distillation with the new Wilton pipe-still



This 150 tons per day distillation plant has been designed and constructed by Chemical Engineering Wiltons Ltd at Caerphilly for the South Western Division of the National Coal Board.

The plant uses the well established Wilton system in a pipe-still specially designed to meet the demand of modern works for efficient operation and maintenance.

A further five Wilton plants of similar design are under construction.

Continuous tar distillation by

Chemical Engineering Wiltons Ltd

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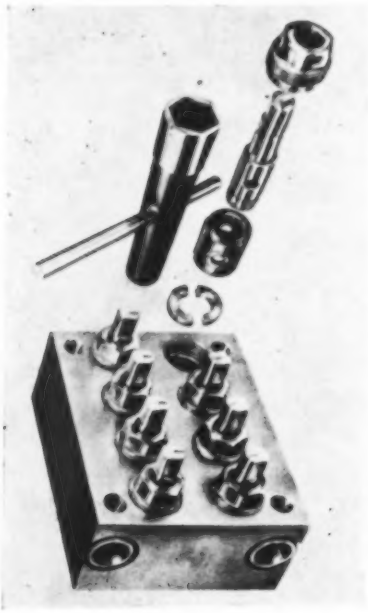
CW. 15

PLANT EQUIPMENT NEWS



manifold arranged in two groups of four, to simplify working and save space. Each cock is sealed by a renewable sleeve of compressed asbestos, which is compressed around a parallel plug with a lapped finish. Stainless-steel eyelets in the sleeve protect the packing from the action of the passing fluid. The illustration shows an eight-unit AB.18 cock manifold with one of the cocks dismantled. The body and the plugs are made from wrought stainless steel, and to prevent the risk of any leakage, each group of four cocks is covered by a sealed bonnet which is only removed when the cocks are to be operated. Proof of the satisfactory working of these cocks was disclosed recently when one of the reactors at Calder Hall was closed down in an endeavour to trace a leak of carbon dioxide. All of the cocks were proved to be free of blame and operating satisfactorily. **Richard Klinger Ltd., Klingerit Works, Sidcup, Kent.**

BCE 1100 for further information

A Miniature Thermostat

Graviner have extended their range of industrial thermostats to include a miniature instrument, the Gravinette. The new thermostat is nominally rated at 1 A × 250 V. A.C., or 2 A × 24 V. D.C., and it operates on a differential expansion principle—a low-expansion alloy bridge mechanism welded to the stainless-steel case moving a spring contact-strip upon change of temperature. The movement causes the contacts either to make or break circuit according to which of the two types of switch is being used. The switch differential is less than 1°C and, depending upon the installation, control within 1°C can be obtained, it is said. The Gravinette can be set in the factory or by the user by turning a self-locking adjusting screw. The electrical connection is made through solder tags which are fixed to the insulating terminal block. **The Graviner Manufacturing Co. Ltd., Colnbrook, Buckinghamshire.**

BCE 1101 for further information

Submerged Combustion

The submerged combustion process finds particular application in the heating and concentration of acid liquors and other corrosive solutions, as it brings the heat into direct contact with the liquid and makes possible the use of containing vessels having corrosion-resistant linings which do not need to transmit heat from the outside. It also eliminates troubles due to scale deposition. At a recent demonstration, plant for submerged combustion made by Nordac used coal-gas and air compressed together in a small blower, and produced complete combustion with less than 10% excess of the theoretical quantity of air. **Nordac Ltd., Uxbridge, Middlesex.**

BCE 1102 for further information

Vane Flow-indicator

The new Bowser Fig. 811 sight flow-indicator is a single-window vane-type indicator for use with clear or translucent liquids. It is suited for use in cooling-water lines, jacket-water lines for diesel engines and other equipment. The vane, visible through the glass, is spring actuated. It assumes a position at right angles to the centre-line of the pipe when there is no flow, and moves at an oblique angle when liquid is flowing. The position

of the vane provides an approximate indication of the quantity moving through the pipe. The indicators can be supplied for pipe sizes from ¼ in. to 2 in. The bodies are made of bronze, and the instruments are designed for a maximum pressure of 75 psi. **Liquid Systems Ltd., Union Road, Croydon, Surrey.**

BCE 1103 for further information

Other Items of Interest

Consolidated Pneumatics have developed a silent screwdriver. The tool, which is in the size ranges 0, 2 and 4 B.A. and $\frac{7}{16}$ in. to ¼ in. B.S.F. and Whitworth, is air powered and weighs only 30 oz. A speed controller is incorporated in the machine. **Consolidated Pneumatic Tool Co. Ltd., 52 Kings Road, Richmond, Surrey.**

BCE 1104 for further information

Flexile Metal have developed a method of hermetically sealing collapsible tubes useful for products that tend to seep. The nozzle of each tube is sealed by a membrane and the folded end is rendered air- and liquid-tight with a latex end-sealing compound. The membrane, which is available on aluminium, tin, tin-coated lead and lead tubes, consists of a film of metal about 0.003 in. thick which is integral with the metal of the tube. The tube is fitted with a Polyflex polythene cap having a spike for piercing the membrane. **Flexile Metal Co. Ltd., 796 Holloway Road, London, N.19.**

BCE 1105 for further information

A new type of machine for chemically and electrically insulating capillary tubing with PVC has been developed by Creators. It covers lengths as small as 30 to 50 ft in thicknesses of PVC from 10 to 15 thou. upwards. The process is adaptable to heavy coils of copper and brass tubing and to copper-covered electrical conductors. **Creators Ltd., Plansel Works, Sheerwater, Woking, Surrey.**

BCE 1106 for further information

The new Ultraphot 11 automatic camera microscope by Carl Zeiss, of Western Germany, will soon be available in Great Britain. The instrument is suitable for visual observation, photomicrography and microprojection on to a ground-glass screen. For metallurgical work special wide-angle objectives for survey photography are available. **Degenhardt & Co., 32 Maddox Street, London, W.2.**

BCE 1107 for further information

Sound Diffusion have introduced a break-link cable fire-detection apparatus. The break-link cable consists of a single flexible conductor which has been cut at 3-ft intervals and joined together with a low-melting point solder normally chosen to liquefy at 120°F. The cable is insulated with PVC, except for the soldered joints, which are left exposed. **Sound Diffusion (London) Ltd., 243 Coastal Chambers, Buckingham Palace Road, London, S.W.1.**

BCE 1108 for further information

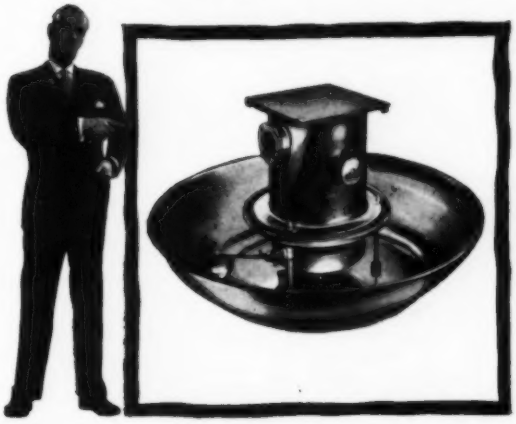
Two products recently made available by Corrosion Proof Products are a chemical-resistant cement for bonding acid-resisting tiles and a heavy-gauge cold-setting membrane, respectively Corro-Proof 'PXY' cement and Corro-Proof 'PXY' resin membrane. They both contain epoxy resins and therefore possess, the makers point out, considerable mechanical strength. **Corrosion Proof Products Ltd., Sunleys Island, Great West Road, Brentford.**

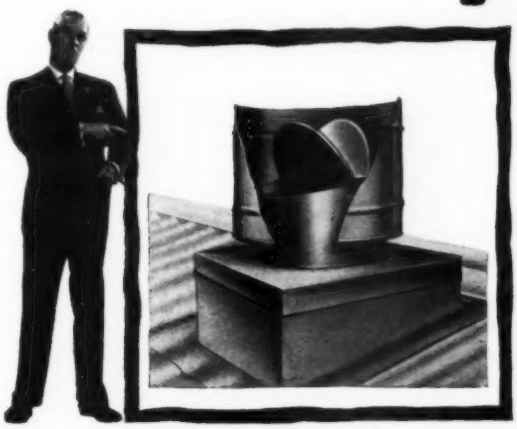
BCE 1109 for further information

Do you KNOW?

The Aerosol-Turbo?

A new humidifier which has already proved of immense value to many industries from Textiles to Tobacco. The Aerosol-Turbo gives trouble-free, controlled humidification, without wetting or water tracking. May we demonstrate this machine at your premises?





The Upblast?

An 'all-year-round' roof unit—the most powerful ventilator ever devised for the dispersal of fumes and vitiated air. Air movements range from 2,000 to 27,000 cu. ft. per minute. When not in use, the automatic stainless steel shutters keep valuable heat in and the elements out. Full details are available on request.

The 'Cycol'?

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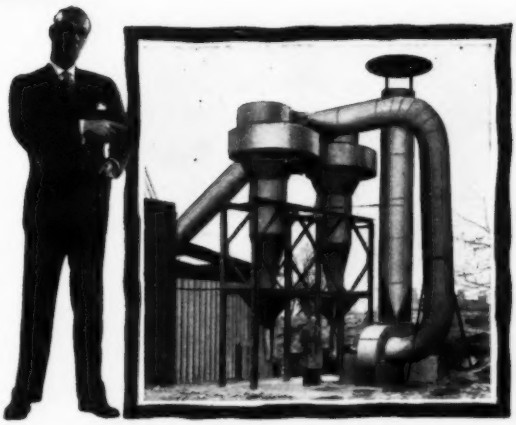

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PLANT EQUIPMENT NEWS

New Publications

"Methods of test for air filters used in air-conditioning and general ventilation" is the title of a new British Standard (2831:1957), price 7s. 6d. Other Standards recently announced are: B.S. 2811: 1957, "British Standards for smoke density indication and recorders", price 3s. 6d.; B.S. 2741: 1957, "Recommendations for the construction of simple smoke viewers", price 3s.; B.S. 2815: 1957, "British Standard for compressed asbestos fibre jointing", price 3s.; B.S. 507: 1956, "British Standard for Ethanol"; B.S. 508: 1956, "*n*-Butanol"; B.S. 551: 1956, "*n*-Butyl acetate"; B.S. 553: 1956, "Ethyl acetate", price 3s. each; and B.S. 2782: 1956, "British Standard for methods of testing plastics", price 10s. Copies of the above Standards may be obtained from the Sales Branch, British Standards Institution, 2 Park Street, London, W.1.

BCE 1110 for further information

A new isotope catalogue (fourth edition) has just been published. This gives the availability of individual pile-produced radio-isotopes and also a table listing their properties. Services supplied by the Isotope Division of A.E.R.E., Harwell, are also given. Copies from Isotope Division, A.E.R.E., Harwell, Didcot, Berkshire.

BCE 1111 for further information

A beautifully produced coloured booklet by B.P. Ltd., describing the methods used by B.P. in their world-wide search for oil, has recently been released. Copies from the British Petroleum Co. Ltd., Brittanic House, Finsbury Circus, London, E.C.2.

BCE 1112 for further information

I.C.I. have issued three titles on "Fluon". These are, respectively, "Polytetrafluoroethylene", "The Industrious Plastic" and "Non-stick Applications". Copies from Imperial Chemical Industries Ltd., Plastics Division, Welwyn Garden City, Hertfordshire.

BCE 1113 for further information

Leaflet 115/0157 covers the new Mark 2 Linatex valve and its design. Copies of this interesting leaflet from Wilkinson Rubber Linatex Ltd., Camberley, Surrey.

BCE 1114 for further information

Hand rodding equipment for sewers is described in Publication OA/2307 by General Descaling Co. Ltd., Worksop, Nottinghamshire.

BCE 1115 for further information

BSIRA Research Report M24, entitled "Determination of Moisture in Solids", by P. J. Geary, surveys the known methods of determining the moisture content of solid materials and lists instruments and other apparatus (for making measurments of moisture content) which can be obtained in Great Britain. British Scientific Instrument Research Association, "Sera", South Hill, Chislehurst, Kent.

BCE 1116 for further information

Two new data sheets (Phosbrite 150 and 159) by Albright & Wilson detail the applications for these two chemical polishing solutions. Albright & Wilson Ltd., 49 Park Lane, London, W.1.

BCE 1117 for further information

Fiscol Ltd. have recently published a useful 28-page reference book on the electro-chemical deposition of metals. Copies from Fiscol Ltd., North Road, London, N.7.

BCE 1118 for further information

A technical circular (TC. 103) dealing with manipulative equipment for manual and automatic arc welding has been issued by Quasi-Arc Ltd., Bilston, Staffordshire.

BCE 1119 for further information

B.X. Plastics have produced a 12-page booklet entitled "Range of Materials". This gives in handy form the type of plastics material, its uses and how it is supplied by B.X. Plastics Ltd., Higham Station Avenue, London, E.4.

BCE 1120 for further information

A new publication (No. 63) by W. C. Holmes, entitled "Benzole Recovery Plant", should prove of interest to all engaged in the chemical engineering field. Well illustrated with both flow diagrams and photographs of plant, the book covers its chosen subject admirably. W. C. Holmes & Co. Ltd., P.O. Box No. B7, Turnbridge, Huddersfield.

BCE 1121 for further information

Griffin & George have announced the publication of a new Laboratory Apparatus Catalogue (565). The catalogue comprises some 700 pages of text, is illustrated and covers over 20,000 items of chemical apparatus. Griffin & George Ltd., Alperton, Middlesex.

BCE 1122 for further information

Publication No. S.T. 12/56 is a six-page leaflet detailing the advantages for Gush chemical pumps (manufactured by Appleton & Howard Ltd., Salisbury Street, St. Helens, Lancashire) in the chemical and process industries.

BCE 1123 for further information

A new four-page leaflet describing ways of entering the civil engineering profession has been produced by The Institution of Civil Engineers, Great George Street, Westminster.

BCE 1124 for further information

Sturtevant have published a 24-page booklet (Publication 3502) which gives a wealth of information on the company's mechanical draught fans. The third edition of Sturtevant's Preciptron electrostatic air-filter handbook has also recently been published. Copies from Sturtevant Engineering Co. Ltd., Southern House, Cannon Street, London, E.C.4.

BCE 1125 for further information

Marchon Products have released a number of new publications. That entitled "Industrial Applications of Surface Active Chemicals" details numerous applications for Marchon synthetic surface-active agents. Other titles include details of Marchon products for the toilet, cosmetic and pharmaceutical industry.

BCE 1126 for further information

Publication No. 68 gives facts and figures on the Holmes-Rothemuhule multi-cell cyclone dust collector. W. C. Holmes & Co. Ltd., P.O. Box 7, Turnbridge, Huddersfield, England.

BCE 1127 for further information

Midland Silicones have just issued a new publication which describes for the first time in general terms the wide and varied uses for silicone-based paints in industry. Reference given is "Silicone Notes L2-1" and copies may be obtained from Midland Silicones Ltd., 19 Upper Brook Street, London, W.1.

BCE 1128 for further information

Airmec Ltd. have produced a well-presented folder containing numerous technical leaflets about their range of products. Airmec Ltd., High Wycombe, Buckinghamshire.

BCE 1129 for further information

Details of the Weir three-throw reciprocating pumps are given in Publication 164, by G. & J. Weir Ltd., Cathcart, Glasgow.

BCE 1130 for further information

Two new booklets ("Shell mouldings as applied to castings in Hindium" and "Hindium 100") give background, applications and specifications for this metal. Copies may be obtained from High Duty Alloys Ltd., Slough, Buckinghamshire.

BCE 1131 for further information

Whiffen & Sons Ltd. have produced an interesting booklet about Zerox, a 35% hydrazine solution which is used for the deoxygenation of boiler feedwater. Whiffen & Sons Ltd., Fison House, 95 Wigmore Street, London, W.1.

BCE 1132 for further information

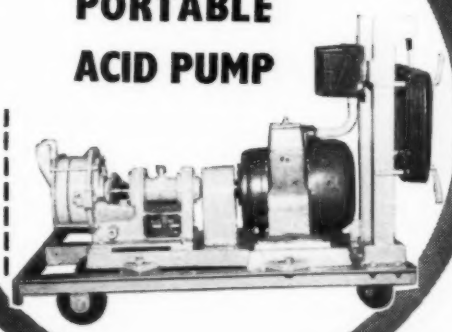
Solartron 1956 is an illustrated annual review of the company's progress and contains a special survey on "Electronics —the spearhead of automation". Solartron Electronic Group Ltd., Thames Ditton, Surrey.

BCE 1133 for further information

Two new publications (227 and 987/157) have just been released by George Kent Ltd. These cover the CM low flow oil meter and the company's Commander KU flow recorder and integrator respectively. The CM is manufactured in one standard size and for flows up to 200 Imperial gallons/hour. George Kent Ltd., Luton, Bedfordshire, England.

BCE 1134 for further information

MITCHELL PORTABLE ACID PUMP



CAPACITY 780 G P H; TOTAL HEAD 25 FT, INCLUDING A SUCTION LIFT EQUIVALENT TO 10 FT OF WATER; STANDARD UNIT FITTED WITH 1½ H P MOTOR FOR 400/440/3/50 ELECTRICAL SUPPLY

CONSIDER THESE ADVANTAGES

EASILY PORTABLE The pump is mounted on a substantial fabricated trolley having rubber tyred wheels and rear castors, so that it is easily portable to any part of the factory.

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SELF-PRIMING The pump is completely self-priming and requires no additional valves or foot valves for its operation. Designed for use with flexible hosing, it is only necessary to place the piping in position and switch on the pump for immediate operation.

UNIVERSAL APPLICATION Being constructed in special corundum material, the pump will deal successfully with all acids, except hydrofluoric, at any concentration and with all alkalis. In addition, it can of course be used for more conventional water pumping duties, and is therefore a pump of almost universal application in many works for odd pumping duties.

WIDE RANGE OF DUTIES The pump can be used for emptying sumps of acids or combinations of acids in waste effluents, emptying carboys, plating vats, tanks and vessels, and for the discharge of road tankers, etc.

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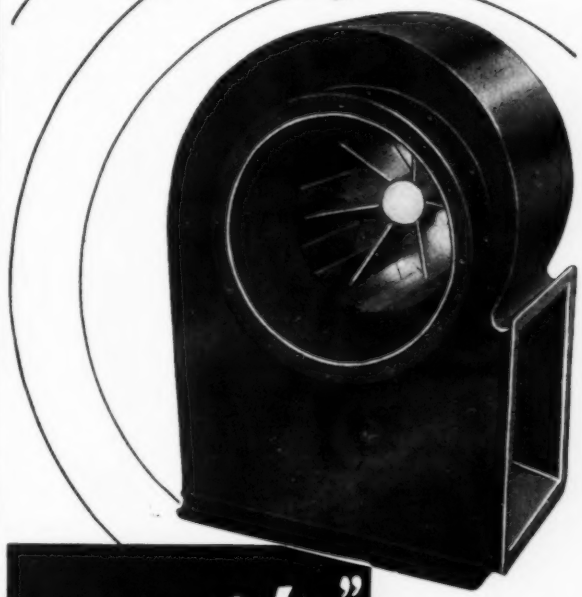

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This is the fan that resists the chemical uction of strong acids, alkalis and moist gases. Steel outer casing. Impeller constructed from rigid P.V.C. and all metal surfaces protected with same material. We design and install complete plants including P.V.C. Ducting and Hoods. Let us have details of your requirements.

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MANCHESTER: City Buildings, 69 Corporation St., 4. *Phone: Blackfriars 6918*

SWANSEA: 256 Oxford Street. *Phone: Swansea 50149*

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The Month's News in Brief

The third annual conference of engineers and others with special responsibilities for standards will take place on Thursday, May 9. This year's conference will be at Church House, Westminster, and application forms for tickets may be obtained from B.S.I., 2 Park Street, London, W.1. A registration fee of £1 1s. (including the cost of a buffet luncheon) will be charged.

Czechoslovakia has ordered a complete plant costing approximately £600,000 for making chipboard or particle board by the Bartrev process. The order was secured by Mr. G. H. Lowe, managing director of International Plastics (East) Ltd., and Mr. M. Culme-Seymour, sales director of International Plastics Ltd.

The British Plastics Federation announced that the plastics industry had another record production and export year in 1956. Output reached about 335,000 tons, an increase of more than 10,000 tons compared with the 1955 total of 324,000 tons. Australia (with imports valued at over £2.75 million) remained the best market, and India (over £2 million), France (£1.6 million), Netherlands (£1.5 million), South Africa (£1.4 million), Sweden (£1.3 million), Italy (nearly £1.2 million) and Denmark (£1 million) were other substantial buyers.

Acalor (1948) Ltd. announce that they have undertaken the building of large concrete tanks which will act as containers for radioactive materials for a new atomic power station now in the process of construction in Scotland.

Wild-Barfield Electric Furnaces Ltd. announce that they have concluded an agreement with Paul Ferd. Peddinghaus, of Gevelsberg, Germany, by the terms of which Paul Ferd. Peddinghaus are appointed sole agents for the sale and service of Wild-Barfield A.H.F. induction heating equipment in Germany, and Wild-Barfield have the right to use Peddinghaus designs of handling fixtures for use on induction heating applications where applicable.

The National Union of Manufacturers announced, at a recent Press conference, the formation of N.U.M.A.S. (National Union of Manufacturers Advisory Service Ltd.). It is a non-profit-making company and is intended to meet the needs of the many industrial companies who wish to improve their efficiency, but who feel that they need guidance and possibly some assistance to supplement their own experience and resources. Full information can be obtained from N.U.M.A.S., 45 St. Paul's Churchyard, London, E.C.1; its managing director is Mr. G. L. Page.

I.C.I. has announced substantial reductions in the price of its wrought titanium and titanium alloy products. While continuing to vary according to the form of wrought product and the grade or alloy of titanium used, prices will in general, be lowered by 10%.

British Hydrocarbon Chemicals Ltd. announces that its two new plants for the production of ethylene and ethanol are now in commercial operation and have doubled the existing capacity for these chemicals.

New plant for the electro-chemical deposition of chromium, which can accommodate components up to 15 ft long, 5 ft diameter, and weighing up to 6 tons, has just been completed at the Port Glasgow works of Fescol Ltd.

The General Electric Co. Ltd. has recently exported to India infra-red plant to speed the finishing of 40-gallon oil drums. Installed at the Calcutta works of The Indian Galvanising Co. (1926) Ltd., the plant copes with an output of some 80 drums an hour.

Quasi-Arc Ltd. are now manufacturing automatic girth welding equipment for the simultaneous welding of internal and external circumferential seams of oil storage tanks from 30 ft to 200 ft in diameter, *in situ*. The time taken with this new equipment is much less than with normal manual welding methods.

A new Research and Development Division has been established by The Pyrene Co. Ltd. Its function will be to further improve co-ordination between the various fire research, development and experimental activities carried out within the company. Air Commodore J. A. Hawkings has been appointed Controller of the new division.

A new company, G. A. Platon Ltd., which has been formed to provide a technical sales service to all industries concerned with the handling of fluids, has acquired from the patentees and Ultrasonics Ltd. the exclusive rights to manufacture and sell the "Flostat", an automatic flow controller. Directors of the new company are Dr. J. W. Mitchell, F. J. Minett and G. A. Platon.

On February 18 all head office departments of the Shell Chemical Co. Ltd. moved to the company's new building at Marlborough House, 15/17 Great Marlborough Street, London, W.1, telephone GERrard 0666. Plastics and resins department will remain at Norman House, 105/9 Strand, London, W.C.2.

Vacu-Blast Ltd. have established a company in France. The company is known as Societe Vacu-Blast (France) and its address is 46 rue Anatole France, Levallois-Perret (Seine), France.

Chemidus Plastics Ltd. have transferred their administrative and sales offices to Dominion Buildings, South Place, London, E.C.2, telephone MONarch 0131.

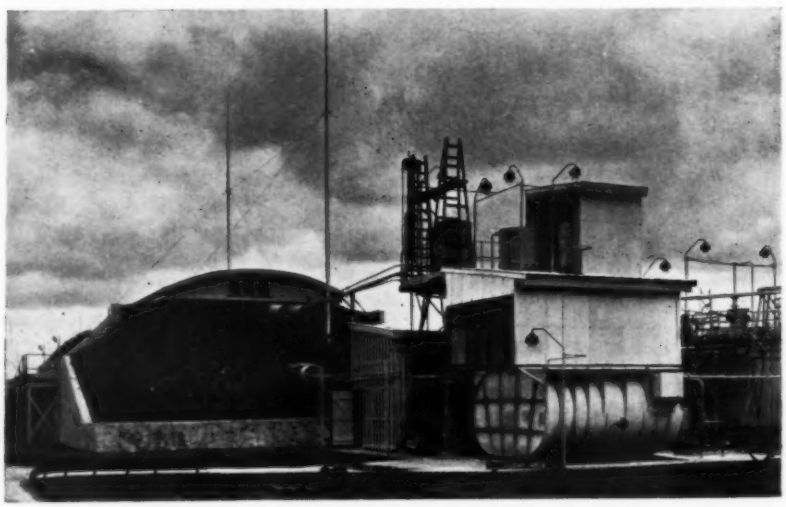
The entire share capital of Thomas Morson & Son Ltd. has been acquired by Merck, Sharp & Dohme Ltd., Hoddesdon. The policy of the company remains unchanged, and Mr. G. T. Morson continues as managing director.

Air Control Installations Ltd. recently opened a new branch office at Cross House, Westgate Road, Newcastle on Tyne, 1 (telephone Newcastle 28861).

The North-eastern area sales office of Midland Silicones Ltd. has moved from its former address to 5/7 New York Road, Leeds, 2 (telephone Leeds 26768).

C. T. (London) Ltd., of 27 Ashley Place, Victoria Street, London, S.W.1, who are the U.K. representatives of Societé des Compresseurs à Membrane Corblin have informed us that the French company also manufacture a range of diaphragm compressors and pumps suitable for high pressures up to 4000 psi or more, in addition to those mentioned in the article "Guide to the Selection of Pumps" in which only low-pressure diaphragms were covered.

Acknowledgement is due to Woodhall-Duckham Construction Co. Ltd., for permission to reproduce the photograph illustrating the Whissoe W-D Electro-detarrers (p. 76, February issue) installed as part of the N.C.B.'s Avenue Carbonisation and Chemical Plant, a description of which was given in our January issue, p. 34.



The newly-built Biazzi nitroglycerine plant now being operated by ICIANZ *at Deer Park, Victoria. Technicians of* ICIANZ *visited I.C.I.'s Biazzi plant at Ardeer to gain operational experience*

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People in the News

Head Wrightson & Co. Ltd. announce the following appointments to the boards of the newly-formed subsidiary companies: Head Wrightson Teesdale Ltd. (formerly Engineering Division of Head Wrightson & Co. Ltd.), **Mr. R. H. Sturgess** (managing) and **Mr. R. Purnell**; Head Wrightson Stockton Forge Ltd. (formerly the Stockton Forge Division of Head Wrightson & Co. Ltd.), **Mr. J. W. Wardell** (managing), and **Mr. R. B. W. Bolland**; Head Wrightson Iron Foundries Ltd. (formerly the Iron Foundries Division of Head Wrightson & Co. Ltd.), **Mr. N. Addison**; and Head Wrightson Iron and Steel Works Engineering Ltd. (formerly the McKee Division of Head Wrightson & Co. Ltd.), **Mr. T. H. Stayman.**

Dr. A. A. Wells, assistant director of research, British Welding Research Association, will leave in June for Washington, D.C., where he is to take up an appointment as Assistant Professor of Civil Engineering in the George Washington University. He hopes to continue there his researches into brittle fracture.

The National Coal Board has appointed **Dr. William Reid** as chairman of the Durham Division in succession to **Mr. E. H. D. Skinner.** The Minister of Power has agreed, at Dr. Reid's request, to the termination of his appointment as a member of the National Board to enable him to take up this appointment. The Durham Division is one of the Board's largest and comprises about 130 pits. The output in 1956 was 25¼ million tons.

Mr. R. B. Dummett has been appointed a director of The British Petroleum Co. Ltd to fill the vacancy on the board caused by the resignation of **Mr. B. R. Jackson. Mr. D. Anderson, Mr. A. E. C. Drake** and **Mr. C. E. Spearing** have been appointed directors of BP Trading Ltd., the company's principal trading subsidiary. **Mr. P. T. Cox** has been appointed managing director of B.P. Exploration Co. Ltd.

Dr. Harold Heywood has been appointed Principal of the Woolwich Polytechnic and will take up his duties in May. He has been Reader in Mechanical Engineering at the Imperial College (University of London) since 1940. He served an engineering apprenticeship at Robey & Co. Ltd., Lincoln, and obtained a Whitworth Scholarship from the Lincoln Technical College. This scholarship was held at Imperial College, since when he has had a wide range of experience in industry, research and teaching at both technical colleges and the University. His research work has been mainly concerned with dust problems in industry, such as air filtration and the production of powdered materials. He has also worked on the direct use of solar energy in tropical countries.

Dr. F. T. Rosser has been appointed vice-president (Administration) of the National Research Council of Canada. He is a graduate of McMaster (B.A. in Honours Science), Western Ontario (M.A. in Plant Pathology), and Ottawa University (Ph.D. in History). He succeeds **Dr. E. R. Birchard,** retiring vice-president (Administration) of the N.R.C. who continues in his position of president of Canadian Patents & Development Ltd.

Mr. W. H. Rogers has been oppointed industrial sales manager of British Oxygen Gases Ltd.

Pfizer Ltd announce the appointment of **Mr. T. Black** as manager of commercial development. Mr. Black, who is a member of the Pharmaceutical Society, was previously a director of Menley & James Ltd., with whom he spent 26 years.

In agreement with the Foreign Office, the Department of Scientific and Industrial Research has appointed **Brigadier C. F. C. Spedding** to succeed **Mr. K. H. Lauder** as Scientific Attaché at H.M. Embassy in Bonn.

The following have been elected officers of the Midlands Section of the Society for Analytical Chemistry for the forthcoming year: chairman: **Dr. R. Belcher**; vice-chairman: **Dr. S. H. Jenkins**; honorary secretary: **Mr. G. W. Cherry**; and honorary treasurer: **Mr. F. C. J. Poulton.**

Mr. H. F. Tremlett has been appointed deputy director of the British Welding Research Association. His appointment at the Abington Research Station became effective on February 1, 1957.

After 33 years with Chloride Batteries Ltd., **Mr. S. H. Chase,** has retired. **Mr. D. S. Howarth** has taken over the position of manager, Stationary Battery Sales.

Dr. Leo Marion, director, Division of Pure Chemistry, National Research Council of Canada, has been named an honorary member of the "Société Chimique de France". Dr. Marion is the first Canadian to receive this honour. The Chemical Society of France, which is celebrating its hundredth anniversary this year, now has 15 honorary members.

Mr. W. J. Cole, who represented the Cambridge Instrument Co. Ltd. in the Liverpool area for the last 27 years, has retired. He is succeeded by **Mr. K. W. Trevatt.**

J. F. Blumenfeld has been appointed to the post of development engineer of General Electric's chemical development department, which is devoted to applied research for new chemical products.

New I.C.I. Appointments

R. Beeching.

J. Ferguson.

L. H. Williams.

C. M. Wright.

J. L. S. Steel.

C. Paine.

M. Jones.

H. C. Raine.

The following appointments have been made to the board of Imperial Chemical Industries Ltd.: **Dr. R. Beeching** becomes technical director; **Dr. R. J. Ferguson** becomes research director; **Mr. L. H. Williams** becomes director in charge of Group B—Dyestuffs and Pharmaceuticals (effective from April 1, 1957, on the retirement of **Mr. P. K. Standring**); **Mr. C. M. Wright** becomes development director. Two changes on the main board of I.C.I. have also been announced: **Mr. J. L. S. Steel** has been appointed economic planning director and **Mr. C. Paine,** previously development director, succeeds Mr. Steel as Group A (Heavy Chemicals) director.

Other appointments recently announced are: **Dr. Maurice Cook** as chairman of the Metals Division, and his place as joint managing director is taken by **Mr. St. J. Elstub. Mr. W. H. G. Lake** and **Mr. W. M. Ismay** are both appointed directors.

With effect from April 1, **Dr. J. M. Holm** will become the joint managing director of the Nobel Division and **Dr. A. D. Lees** will become a director. With effect from February 14, **Dr. W. A. Caldwell** became development director of the Division.

Dr. J. S. Gourlay has been appointed chairman of the Paints Division, and **Mr. J. C. H. McEntee** has been made chairman of the Wilton Council. His place as managing director has been taken by **Mr. R. E. Newell.**

Mr. Maldwyn Jones has been appointed development director and **Mr. H. C. Raine** research director of the Plastics Division. **Mr. L. M. Smith** has been appointed sales manager of the Plastics Department, Northern Region Sales.

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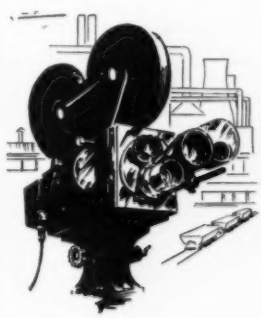

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